The Journal of Bone and Joint Surgery

The Official Publication of

The American Orthopaedic Association
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The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association
Western Orthopedic Association

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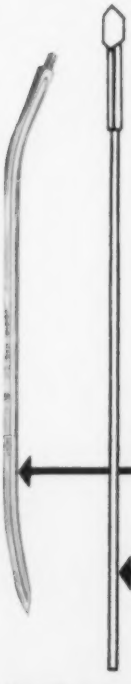

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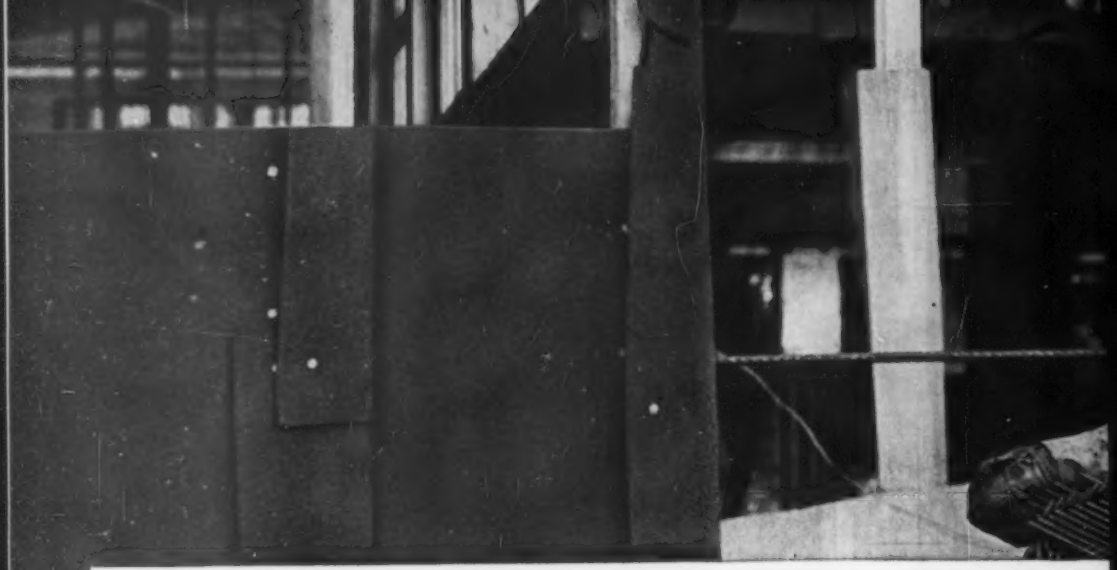

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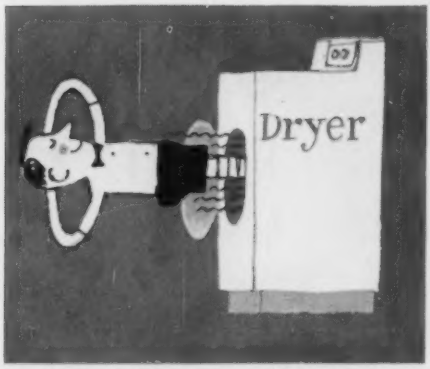

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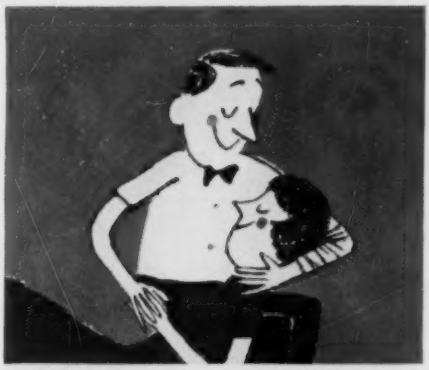

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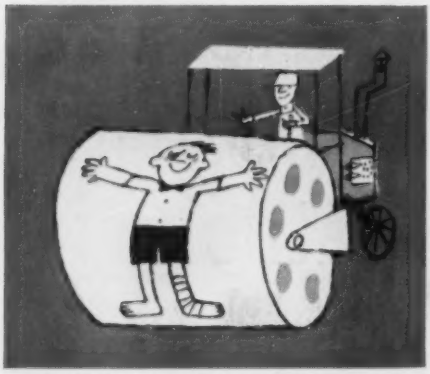

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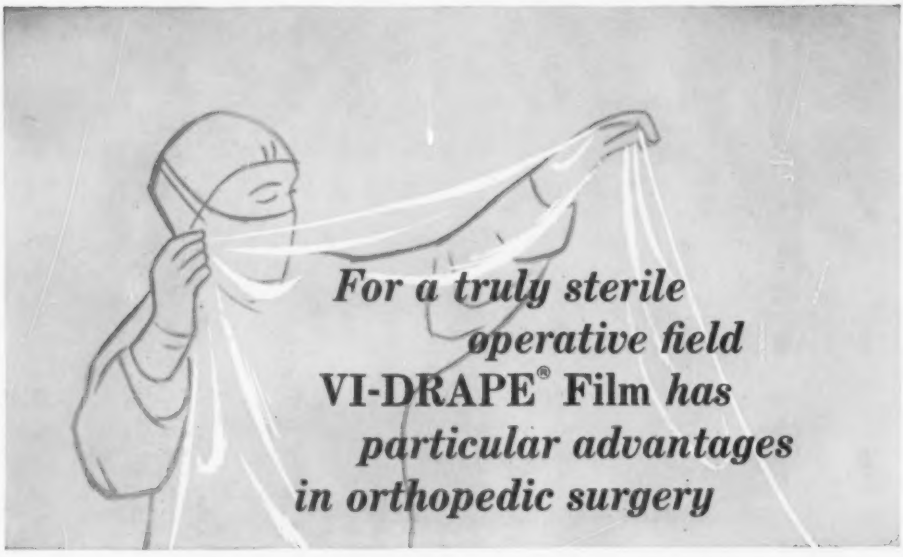

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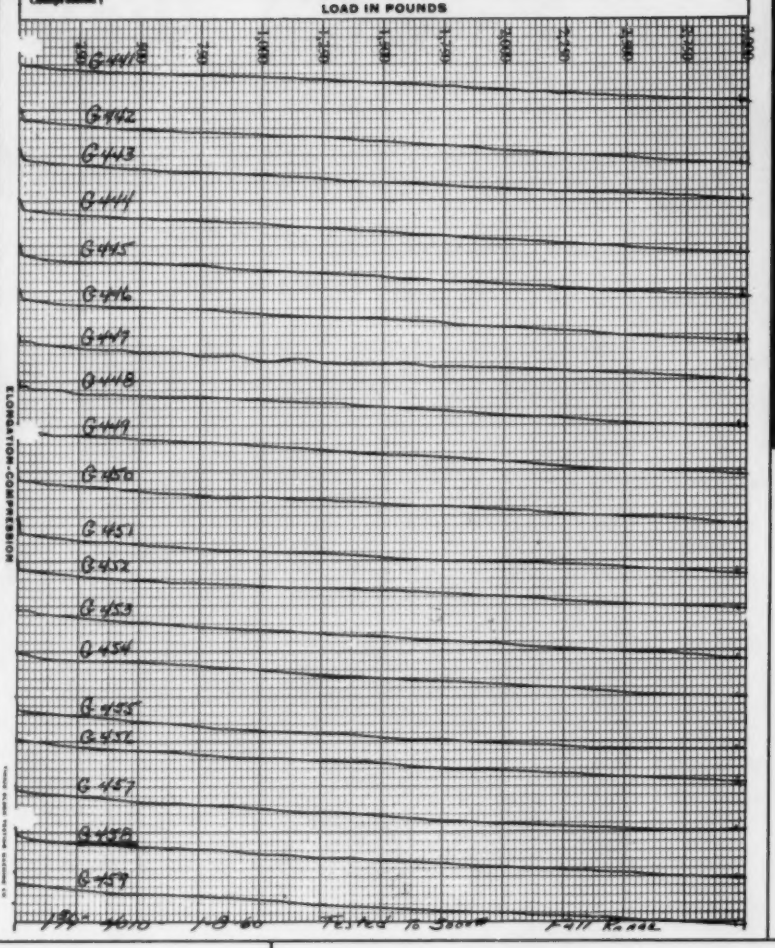

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PUR. ORDER NO.	VENDOR	ADDRESS
C 6731	Zimmer Mfg. Co., Warsaw, Indiana	

RECEIVING REPORT NO.	P.O. NO.	QUAN. RECEIVED	QUAN. INSPECTED	QUAN. DEFECTIVE
		20	20	None

20 pcs. of the following serial numbers have been delivered to the shipping department. All castings have passed mechanical test, radiographic, Zyglo, and visual examination. Certification of chemical analysis of material used is on file and conforms to engineering specifications.

G441 G442 G443 G444 G445 G446 G447 G448 G449 G450 G451 G452

G453 G454 G455 G456 G457 G458 G459 G460

INSTRUCTIONS AND REMARKS:

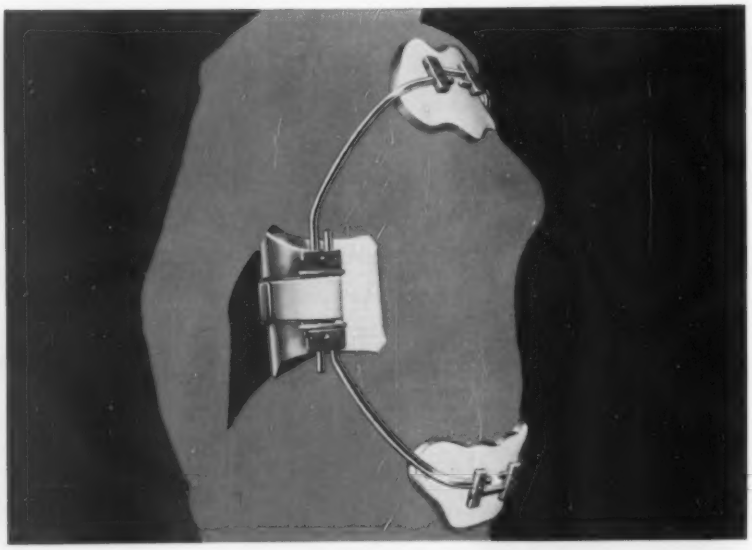
DISPOSITION						APPROVAL		INSPECTOR
ACCEPT	REJECT	RETURN	REPAIR	MAT. REVIEW	SALVAGE	INSP.	ENG.	
20								

CC: MDIR
64010

ZIMMER MFG. CO.

CAMP HYPEREXTENSION BRACE

positive control with minimum patient discomfort

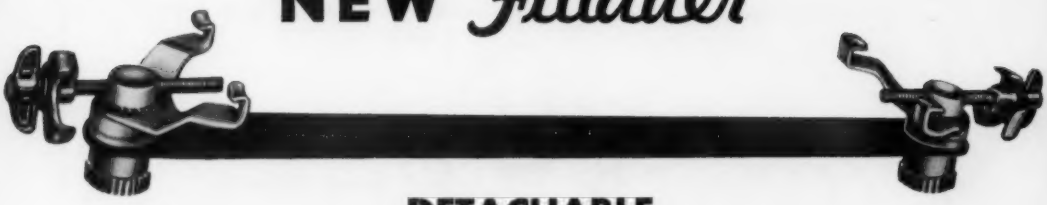


A Camp spinal brace for positive hyperextension in cases of compression fractures, osteoporosis with kyphosis, spinal arthritis, adolescent epiphysitis and osteochondritis. Completely rotating pads at sternal and pubic regions eliminate pressure edges and minimize patient discomfort. In many cases the Camp hyperextension brace eliminates necessity for body casts and is definitely indicated in older patients where it is desirable to eliminate the heavy weight of plaster casts and their constricting effect on the abdomen and chest. Telescoping frames allow easy adjustment to the most exacting prescriptions. Camp trained fitters are ready to assist in immediate application.

S. H. CAMP & COMPANY, JACKSON, MICHIGAN

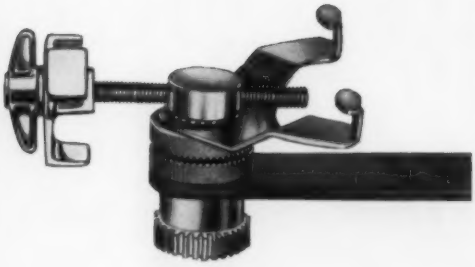
S. H. Camp & Company of Canada, Ltd., Trenton, Ontario

NEW *Fillauer*



DETACHABLE

DENIS BROWNE NIGHT SPLINT



STREAMLINED and IMPROVED

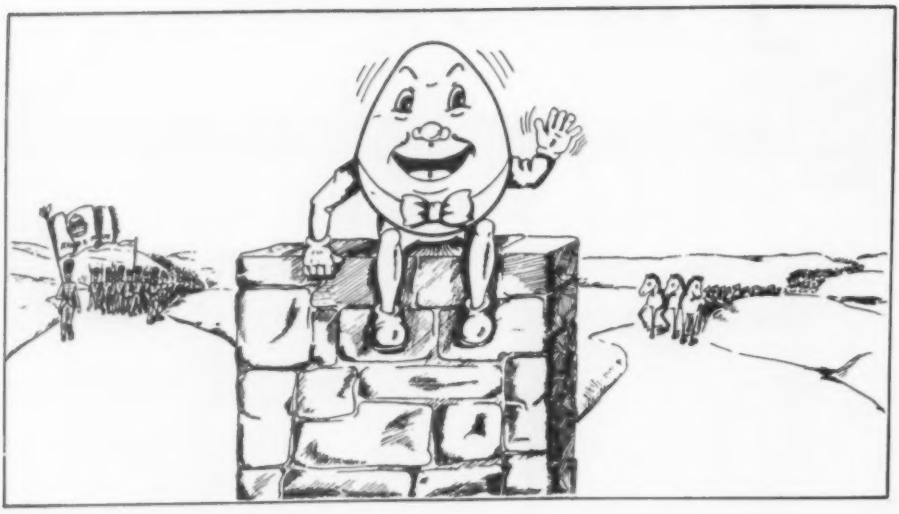
1. Precision die cast Serrated Discs permit 50 positions.
2. New Knurled Screw locks discs in position.
3. New Triple Flange fits club foot shoes or any sole thickness.
4. Streamlined Wing Screw secures flange to shoe sole.
5. Durable, attractive red alumilite color on bars.
6. Lengths 6, 7, 8, 9, 10, 12, 14, 16 and 18 inches. Special lengths to 30 inches at no extra cost.

ORTHOPEDIC SURGEONS recognize the decided advancements this versatile splint affords in treating club feet, positional deformities, tibial torsions, flat feet and congenital hip dislocations. Also applicable for any other deformities that are actively corrected by incessant kicking.

Very little adjustment by surgeon or orthotist is required to fit and position this new Fillauer Detachable Splint.

Pre-walker or larger surgical and club foot shoes work extremely well with the Fillauer Splint. Outgrown shoes may be used by cutting out toes.

Fillauer SURGICAL SUPPLIES, INC.
BOX 1678 CHATTANOOGA, TENN.
ESTABLISHED 1914 Manufacturers of Orthopedic Supplies



Humpty Dumpty sat on a wall
Humpty Dumpty had a great fall,
All the king's horses and all the king's men
Couldn't put Humpty Dumpty together again.

Because . . . In that day they did not have

The RUSH® MEDULLARY PIN
Pat. No. 2,579,968

PATIENT aire

for under
CAST VENTILATION

We are proud to introduce PATIENT-AIRE, another product of Conco's research into modern materials for modern medicine.

- *reduces itching*
- *prolongs cast life*
- *dries cast*
- *diminishes odor*
- *avoids ulceration*
- *cools under cast*
- *warms under cast*
- *X-ray permeable*

CONCO
SURGICAL PRODUCTS, INC.

RESEARCH • DEVELOPMENT • PRODUCTS
BRIDGEPORT • CONNECTICUT

THIS *Spencer* DOES THE JOB OF A BRACE *and More!...*

This patient's kyphosis results from degeneration of the 7th and 8th thoracic vertebrae. Subsequent complications include a fractured pelvis, fractured hip and major abdominal surgery.

The patient could not tolerate her heavy, tiring brace after the abdominal surgery, and obtained an Individually Designed Spencer because . . .

- Designed for her alone, it provides proper abdominal support and aids her general health.
- Proper application of rigid steels provides the exact degree of immobilization prescribed for the kyphotic vertebral column . . . with comfort and cosmetic acceptance.
- In her Spencer, she looks better, feels better and leads a full, productive life.

Each Spencer is individually designed to incorporate the exact features prescribed in the basic style indicated by the patient's figure needs.

Spencer first realigns the body...Then designs a support to hold it that way

Spencer's Individual Designing Service is available to you through Corsetieres specially trained to help you help your patients.

SPENCER®

individually designed supports for men, women and children

SPENCER, INCORPORATED
19 Ellsworth Ave., New Haven 7, Conn.
Canada: Spencer, Ltd., Rock Island, Quebec
England: Spencer, Ltd., Banbury, Oxon

☐ Send me the name of the nearest Spencer Corsetiere.

☐ I would like an office demonstration of Spencer benefits and features.

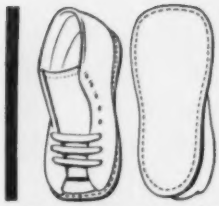
Name _____

Address _____

_____

1-61

Look to the shoes



Pre-Walker, reverse or straight last

that have

Pigeon-Toe, for mild supination

earned the

Super-Pedic, for extreme pronation

confidence of the

medical profession.

Prona-Pedic, for extreme supination

CorecTreds

CorecTred, for mild pronation

and

Thomas Heel Extended Counter

Pedics by **Edwards**

For over 60 years **Edwards** has sought to develop a *complete line* of fully adaptable, quality shoes, at sensible prices, to meet doctors' special prescription requirements. Using tested lasts from clinic-approved patterns, **Edwards** experienced craftsmen developed CorecTreds and Pedics, the most versatile shoes available, sold by conscientious retailers trained in prescription fitting.

Whatever your prescription requirements, examine and advise CorecTreds and Pedics by **Edwards**!

Edwards
THE SHOE FOR CHILDREN
®

PHILADELPHIA 7, PA.

FREE EDWARDS NEW PEDIC KIT

Now, receive Edwards new, complete Pedic Kit designed especially for you. It contains:

- WEDGE CHART
- PEDICGRAPH
- PRESCRIPTION PADS
- CORECTRED FOLDERS
- PEDIC BROCHURES
- HAPPY FEET BOOKLET

Simply Detach This Portion of Advertisement, Mail With Your Personal Letterhead to Edwards Shoes, 314 N. 12th St., Phila. 7, Pa.

Now! Gypsona brings you a creamy plaster bandage that retains its full strength after dipping and squeezing

New L. P. L. Gypsona lets you mold strong, light, longer-wearing casts—with fewer bandages

Until now, a tariff was paid to the drain bucket. Needed plaster strength was sometimes squeezed out, washed away.

Now, however, with the perfection of L.P.L. (Low Plaster Loss) Gypsona, you can mold 96% of the plaster into the finished cast. Now, newly developed adhesive agents securely anchor the plaster to the base cloth.

The difference is immediately apparent

Here you see two bandages being subjected to approximately the same amount of pressure after dipping. The disparity between the ordinary bandage and L.P.L. Gypsona is clearly evident. The Gypsona drainage is almost clear water.

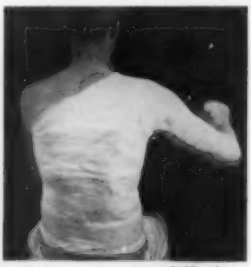
The implications are many

Most certainly, you will use fewer bandages—a cheery note for the keeper of the budget. There's less residue to contend with. You have cleaner handling throughout.

You also enjoy advantages that have long endowed the international prominence of Gypsona.

Creamy, conformable and tough

The deeply buried leno fabric molds firmly about bones, protuberances and indentations. The comfortable Gypsona creaminess, as always, is a pleasure to work with.



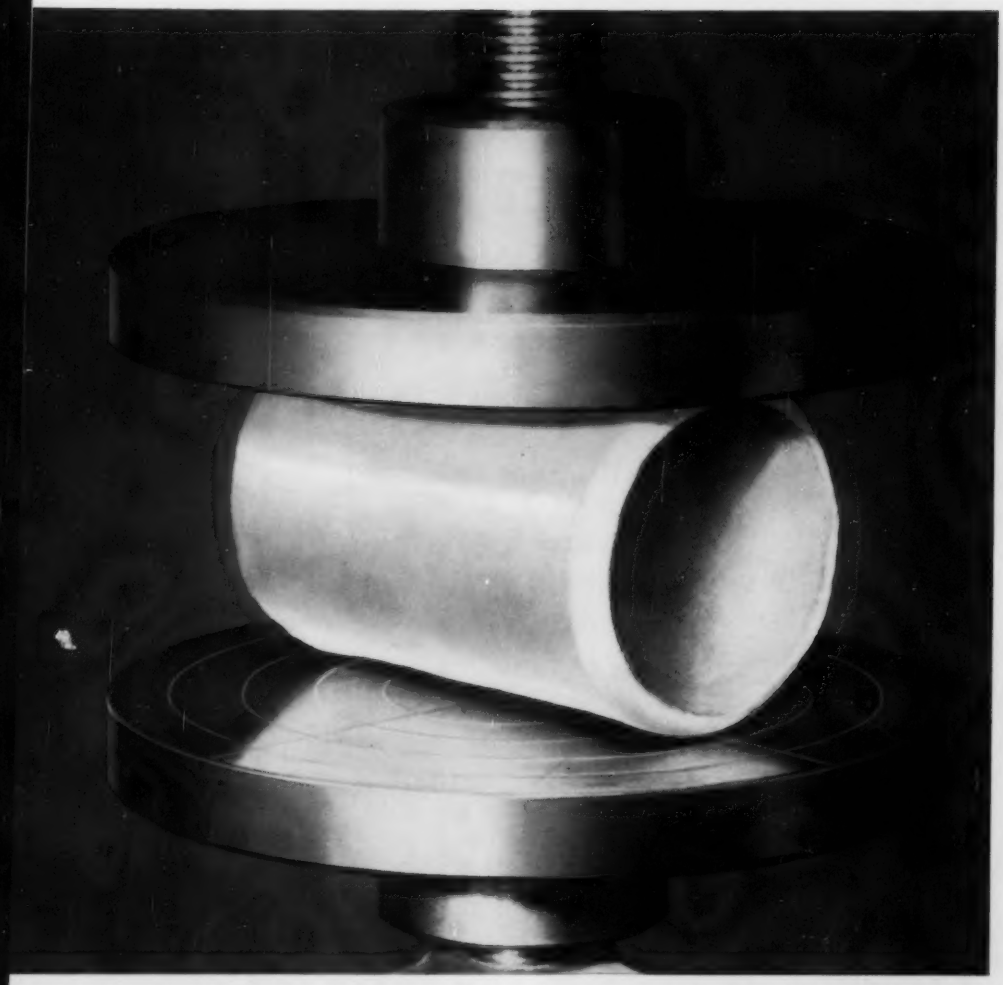
Now your most difficult bandages can be made with creamy smooth, extra strong L.P.L. Gypsona.

The threads do not slide. There is no sawtooth edge. The finished cast has the rich, polished glint that comes only of fine English-quarried plaster.

Price is still the same

Not to be overlooked is the ease of unwinding with the Gypsona plastic core, which prevents telescoping. Plaster stays fresh, almost indefinitely, in the airtight Gypsona package. And the price is still the same as standard Gypsona plaster bandages.

For a first-hand demonstration of L.P.L. Gypsona, get in touch with your Bauer & Black representative.



In the course of precision testing, a single L.P.L. Gypsona bandage, 4 inches wide and 3 yards long, was molded into a standard cylinder. After 24 hours, the cast was submitted to the strength-measuring apparatus above. The cast endured 304 lbs. pressure before it was crushed beyond a functional shape.

Curity®

L.P.L. Gypsona*

PLASTER BANDAGES

THE KENDALL COMPANY
BAUER & BLACK DIVISION

*Reg. T. M. of T. J. Smith and Nephew Ltd.

In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

New, more effective analgesic

Kills pain

stops tension

For neuralgias, dysmenorrhea, upper respiratory distress, and postsurgical conditions...new compound kills pain, stops tension, reduces fever—gives more complete relief than other analgesics.

Soma Compound is an entirely new, totally different analgesic combination that contains three drugs. First, Soma: a new type of analgesic that has proved to be highly effective in relieving both pain and tension.* Second, phenacetin: a "standard" analgesic and antipyretic. Third, caffeine: a safe, mild stimulant for elevation of mood. As a result, the patient gets more complete relief than he does with other analgesics. Soma Compound is nonnarcotic and nonaddicting. It reduces pain perception without impairing the natural defense reflexes.*

NEW NONNARCOTIC ANALGESIC

soma® Compound

Composition:
Soma (carisoprodol), 200 mg.; phenacetin, 160 mg.; caffeine, 32 mg.
Dosage: 1 or 2 tablets q.i.d.
Supplied: Bottles of 50 apricot-colored, scored tablets.

NEW FOR MORE SEVERE PAIN

soma® Compound + codeine

BOOSTS THE EFFECTIVENESS OF CODEINE: Soma Compound boosts the effectiveness of codeine. Therefore, only ¼ grain of codeine phosphate is supplied to relieve the more severe pain that usually requires ½ grain. **Composition:** Same as Soma Compound plus ¼ grain codeine phosphate. **Dosage:** 1 or 2 tablets q.i.d. **Supplied:** Bottles of 50 white, lozenge-shaped tablets; subject to Federal Narcotics Regulations.

*References available on request.

WALLACE LABORATORIES • Cranbury, N. J.

Child Life SHOES

NOW,

The Surgical Boot with Arch Feature Support

Note detail of tonque construction, which holds tonque straight — prevents slipping to side.

- Chrome Retanned Leather Outsole
- 100% Goodyear Welt Construction
- Shaped and Tempered Spring Steel Shank
- Thomas Heel Arch Extension
- Inner Wedged Thomas Heel
- Broad Toe Area
- Long Inside Counter
- Available for Children 4 Months to 10 Years
- Mismate Service Available

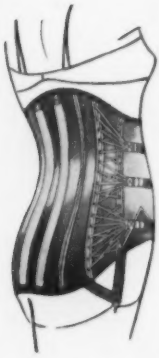
When Mismated Shoes are Needed
CHILD LIFE Gives Special Delivery, Parcel Post Service

For the Name of Your Authorized CHILD LIFE Dealer — Trained to Fill Your Shoe Prescription Exactly as You Prescribe — Write

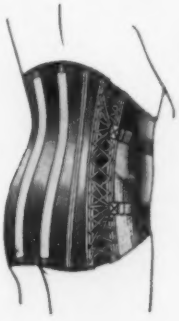
HERBST Shoe Manufacturing Company
P. O. Box 2005, Milwaukee 1, Wisconsin

FOR
ORTHOPEDIC
APPLICATIONS

Freeman SURGICAL SUPPORTS



MODEL 423
Sacro-Lumbar Back
Support for Women



MODEL 422
Sacro-Lumbar Back
Support For Men

For 68 years Freeman has worked closely with orthopedic surgeons to design surgical garments that provide *correct* support. Each garment is made by skilled craftsmen using the finest materials available.

There's a quality Freeman support for most every application. You can be certain that the garment you select will carry out your prescription to the best possible satisfaction of you and your patient.

Freeman corset-type back supports provide bracing in any desired degree to almost complete immobilization. Special construction features assure comfort for the wearer in sitting, standing and reclining positions.

FREEMAN QUALITY FEATURES

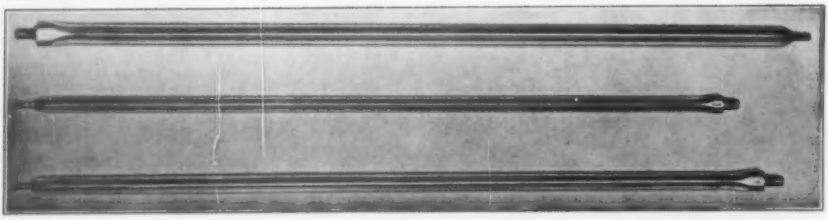
New Dacron-Pima Cotton Fabric. Petal-Soft Interior Finish cushions the stays, avoids irritation. Self-Smoothing, Exclusive Non-Wrinkle Fly speeds putting on garment and avoids comfort-robbing wrinkles. Soft Plush Padding under hooks and eyes. Superb Needle Work.

Prescribe **FREEMAN** *with Confidence!*

Write over your letterhead for
Freeman's illustrated catalog.

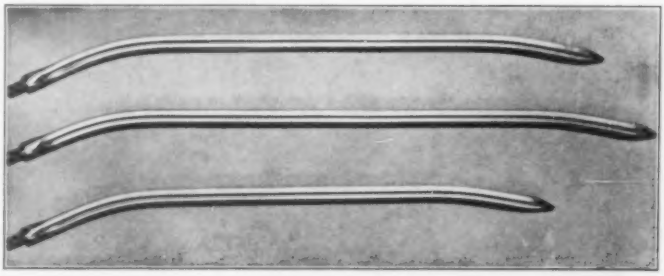
FREEMAN MANUFACTURING COMPANY
Dept. 701, Sturgis, Michigan

LOTTES NAILS and INSTRUMENTS

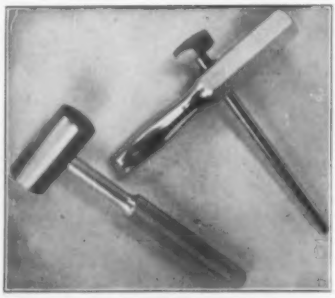


***LOTTES* FEMORAL NAILS** are manufactured with diameters of **⅜, 7/16,** and **½** inches —with lengths in ½ inch variations from 14 to 20 inches.

***LOTTES* TIBIAL NAILS** are made in 5/16 and ⅜ inch diameters—in lengths from 9 to 15½ inches, in variation of ½ inch.



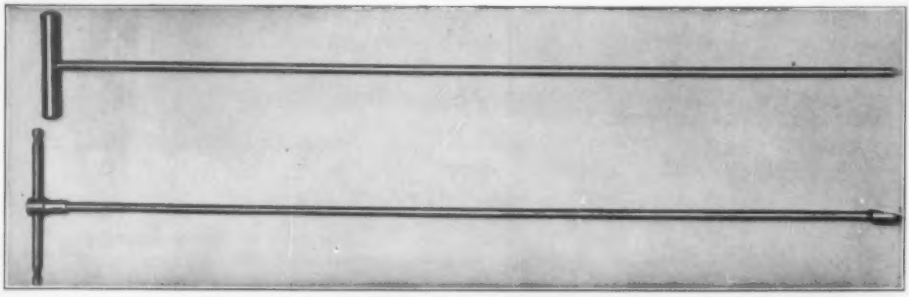
***LOTTES* NAILS AND INSTRUMENTS ARE MADE OF 18-8 SMo STAINLESS STEEL**



***LOTTES* DRIVER-EXTRACTOR COMBINATION and *LOTTES* MALLET**

***LOTTES* GUIDE WIRE AND *LOTTES* REAMER**

The reamer comes in 3 diameters: ⅜, 7/16, and ½ inch—all are 23 inches in length.



CHAS. A. SCHMIDT SURGICAL INSTRUMENT COMPANY

3689 Olive Street, Saint Louis 8, Missouri

A Work of Art

by Waylande Gregory (American Contemporary). This terra cotta exemplifies the high level of creativity for which this highly versatile sculptor is known.

A Work of Art

With STUCCA Plaster of Paris bandage you create a work of art . . . a perfect cast . . . with speed, strength, fidelity – assuring firm support and immobilization for every type of fracture, every time.

STUCCA's creamy, consistently smooth plaster is easily applied, conforms precisely to body contours and, when dry, can take heavy abuse – so important with active children! And it's lightweight, too.

STUCCA's great final strength means you can construct lighter casts thus providing greater patient comfort and reduced X-ray exposure time.

Extra-fast setting time, 2-4 minutes. Or, you can control the setting speed yourself.

For complete data and FREE sample sufficient for your own testing purposes, write today.

ACME STUCCA

ACME COTTON PRODUCTS CO., INC.
245 FIFTH AVE., NEW YORK 16, N. Y.

advanced training for HANGER prosthetists

Certified Prosthetists from the various HANGER offices have attended special courses on Upper- and Lower-Extremity Prosthetics ensuring that HANGER Clients receive the best Prosthetic Service possible.

These courses utilize many of the most recent findings of engineering and prosthetics research, and are designed as advanced training for men already actively engaged in rehabilitating amputees. The courses are approved by the American Board for Certification and given at the University of California in Los Angeles, Northwestern University, and at the College of Engineering, New York University, in cooperation with the Prosthetic Research Board of the National Academy of Sciences.

The use of the Adjustable Leg and the new "quadrilateral socket" were features of a series of intensive courses. The curriculum was based upon the Clinical Approach to Prosthesis, centered around the Clinical Team (illustrated). This team is usually composed of a physician, a prosthetist and a therapist. It is concerned with the integrated handling of each amputee case, including prescription, fitting and check-out of the prosthesis and gait analysis and training of the wearer.

This advanced training enables HANGER Prosthetists to work closely with surgeons and physicians. Doctors interested in Prosthetics can be assured that HANGER Prosthetists are fully acquainted with the latest prosthetic methods. Be sure to call on HANGER whenever you feel we may be of service.

Hanger PROSTHETICS

AVAILABLE AUTHORIZED FACILITIES IN THE FOLLOWING CITIES:

Eastern Region:

BALTIMORE 1, MD.
BOSTON 15, MASS.
CHARLESTON 1, W. VA.
NEW YORK 11, N. Y.
PHILADELPHIA 7, PA.
RALEIGH, N. C.
RICHMOND 19, VA.
ROANOKE 12, VA.
WASHINGTON 13, D. C.

Midwestern Region:

CHICAGO 5, ILL.
CINCINNATI 29, OHIO
DALLAS 1, TEXAS
EVANSVILLE, IND.
FORT WAYNE, IND.
INDIANAPOLIS 2, IND.
OKLAHOMA CITY 3, OKLA.
PEORIA 4, ILL.
ST. LOUIS 66, MO.

Southeastern Region:

ATLANTA 9, GA.
BIRMINGHAM 1, ALA.
COLUMBIA 1, S. C.
JACKSONVILLE, FLA.
LAFAYETTE, LA.
MIAMI 37, FLA.
MOBILE, ALA.
MONTGOMERY, ALA.
NASHVILLE 5, TENN.
NEW ORLEANS 19, LA.
ORLANDO, FLA.
SAVANNAH, GA.
ST. PETERSBURG, FLA.
TAMPA 2, FLA.
WEST PALM BEACH, FLA.

Central Region:

COLUMBUS 8, OHIO
PITTSBURGH 1, PA.

In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

Reprints suitable for framing available upon request

Stryker **Today's concept in skin grafting . . .**

ROLO-DERMATOME

This modern, power operated Dermatome feels well balanced in your hand. Only the disposable blade oscillates to cut accurate grafts set by a single lever, from 5/1000 to 30/1000. Adjustable widths — 1¼, 2¼ and 3 inches. Rollers flatten the skin to eliminate tension as skin comes in contact with the blade.

Always available on 30 day trial.

Stryker

SURGICAL AND HOSPITAL EQUIPMENT

Orthopedic Frame Company

420 ALCOTT STREET • KALAMAZOO, MICHIGAN

STRUCTURALLY SOUND

SMo

TYPE 316

NEUFELD FEMORAL NAIL PLATES

have been engineered to provide maximum strength at the bend. Available in either Neutrilium (cobalt alloy) or type 316 stainless steel with screws of identical metals . . . The Neufeld nail is the choice of careful, discriminating orthopedic surgeons.

Ask your Surgical Supply Dealer or
write for additional technical information

MEDICAL RESEARCH SPECIALTIES
Loma Linda, California

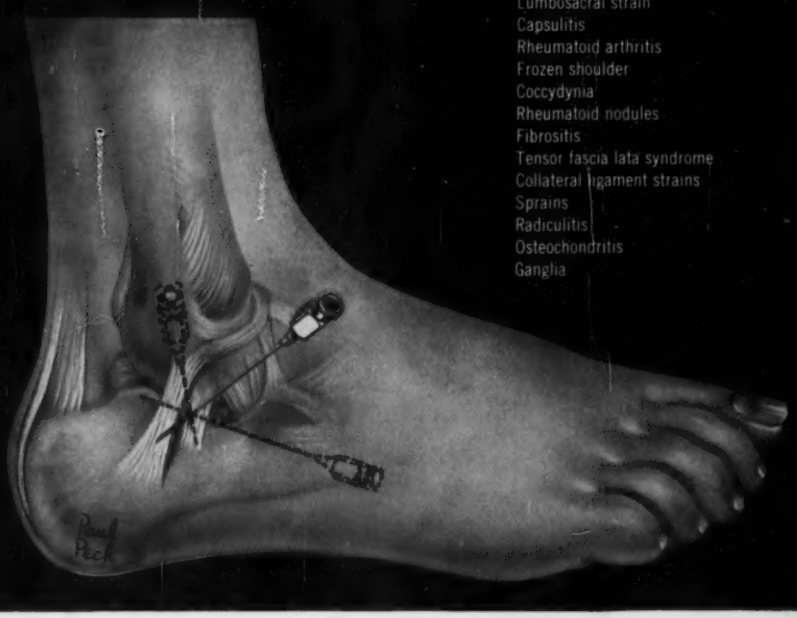
In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

HYDELTRA®-T.B.A.

(Prednisolone *tertiary*-butylacetate, Merck)

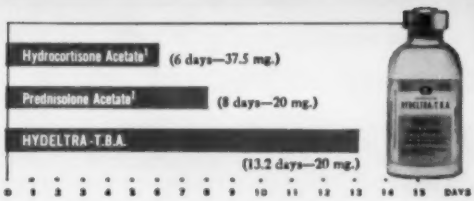
for relief that lasts—longer

in *SPRAINS*—
reduces tenderness,
swelling and
limitation of motion



- Osteoarthritis
- Acute gouty arthritis
- Bursitis
- Tendinitis
- Trigger finger
- Peritendinitis
- Trigger points
- Tennis elbow
- Lumbosacral strain
- Capsulitis
- Rheumatoid arthritis
- Frozen shoulder
- Coccydynia
- Rheumatoid nodules
- Fibrositis
- Tensor fascia lata syndrome
- Collateral ligament strains
- Sprains
- Radiculitis
- Osteochondritis
- Ganglia

Anti-inflammatory effect lasts longer than that provided by any other steroid ester


Hydrocortisone Acetate[1]
(6 days—37.5 mg.)
Prednisolone Acetate[1]
(8 days—20 mg.)
HYDELTRA-T.B.A.
(13.2 days—20 mg.)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 DAYS

Dosage: the usual intra-articular, intra-bursal or soft tissue dose ranges from 20 to 30 mg. depending on location and extent of pathology.

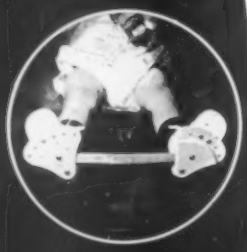
Supplied: Suspension 'HYDELTRA'-T.B.A.—20 mg./cc. of prednisolone *tertiary*-butylacetate, in 5-cc. vials.

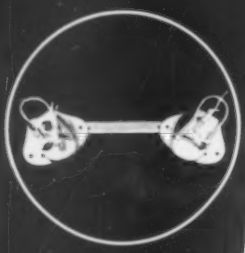
MERCK SHARP & DOHME
DIVISION OF MERCK & CO., INC.
PHILADELPHIA 1, PA.

T&G

ORTHO-AIDE SPLINT

- UNIQUE ESTHETIC APPEAL
- FLAT BOTTOMS
- LIGHTWEIGHT





- SMOOTH PLASTIC SURFACES — Interchangeable, tough, plastic platforms feature smooth, sweeping, polished contours. They slide on the crossbar in either inversion or eversion orientation, maintaining shoes in 15° increments from 0° to 75°. The smooth bottoms are devoid of sharp projections that otherwise prevent the patient from standing and tend to catch on rugs, clothes, and bedding.
- ADJUSTABLE ALUMINUM CROSSBAR — Threaded in ½ inch increments, the adjustable crossbar permits on-the-spot heel-to-heel span adjustments.
- POSITIVE SHOE FASTENING — Three strategically placed, threaded, "tee-nut" rivets firmly secure the shoes — regardless of type or size of shoe. In addition, the shoes can be easily removed by the parent.
- SIMPLE ADJUSTABILITY — Of removable stainless steel machine screws combine the functions of orientating and setting the splint. This way any adult can make adjustments with a facsimile of a screwdriver. Furthermore, the adjustments are inaccessible to even the most astute patients.

NEW AND PRACTICAL CONCEPTS

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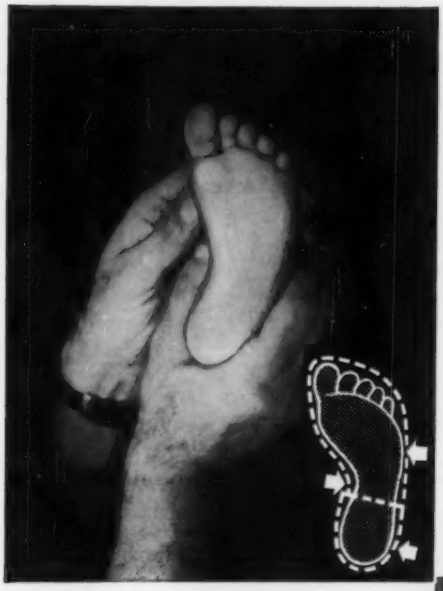

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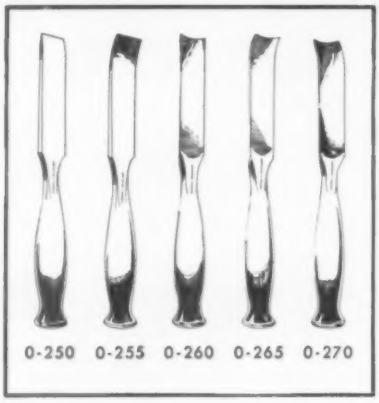

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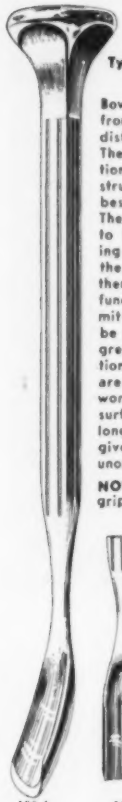

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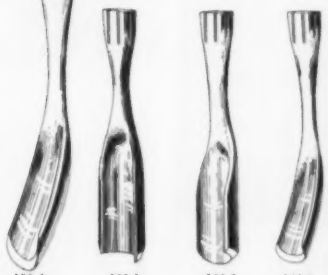

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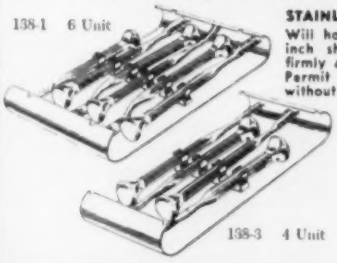

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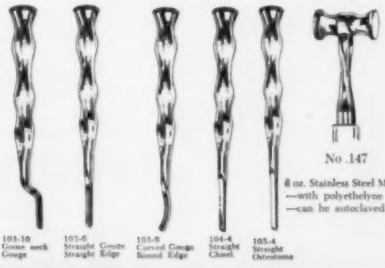

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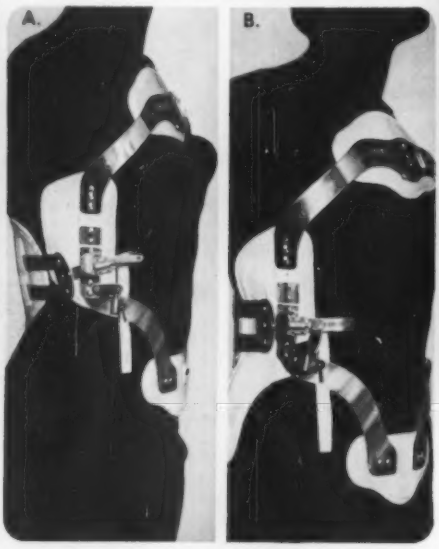

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The Journal of
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Giant-Cell Tumors of Bone (Osteoclastoma)

A Pathological and Histochemical Study

BY FRITZ SCHAJOWICZ, M.D., BUENOS AIRES, ARGENTINA

From the Center of Osteoarticular Pathology and the Department of Orthopaedic Surgery and Traumatology, Italian Hospital, Buenos Aires

The ontogeny of giant-cell tumors of bone still remains the subject of considerable controversy, and many important questions remain unanswered in connection with the histogenesis and clinicopathological diagnosis of these tumors. The separation of the true giant-cell tumor of bone from the group of so-called variants and from the other dysplastic or dystrophic bone lesions, with which it has been confused in the past, is still not accepted by all authors. True giant-cell tumors can no longer be considered innocent growths; on the contrary, they represent a progressive process which can recur, undergo sarcomatous transformation in about 10 per cent of the cases, and even produce metastases without apparent previous malignant alteration. The alleged variants, on the other hand, usually have a favorable evolution, and can be cured with curettage or roentgen therapy in low doses.

Many bone lesions are classified as giant-cell tumors merely because of their roentgenographic appearance or because of the presence of giant cells in the histological preparations, when actually the lesions so classified are really of minor clinical importance. This loose method of classification has contributed to the prevailing confusion and has prevented the establishment of uniform criteria for the therapy of giant-cell tumors.

One of the most important questions, which is raised in nearly all papers concerning this subject, is the reliability of grading of giant-cell tumors as a guide to prognosis, that is, is it possible to predict with any assurance the ultimate outcome of a given case on the basis of the initial histology of the tumor? Grading of these tumors was proposed many years ago by Stewart [91] and Ewing [20] and especially emphasized by Jaffe, Lichtenstein, and Portis [39] who separated benign, aggressive, and malignant types. Meyerding and Broders [55], the Bone Sarcoma Registry, and many others, distinguish a benign and malignant form.

On the other hand Geschickter and Copeland [23,24], Willis [100], Russell [71], and lately Williams, Dahlin, and Ghormley [99] have contended that giant-cell tumors which prove to be aggressive or frankly malignant are not initially distinguishable histologically from those with a benign course. Recently, Jaffe [36] called the giant-cell tumor a rather treacherous lesion and Coley, Higinbotham, and Kogure [14] termed it an unpredictable neoplasm.

Jaffe [38] mentioned four cases in which pulmonary metastasis occurred without the original tumors or their metastases ever developing frankly malignant histological characteristics. He stated that unfortunately one really cannot predict from the histological pattern which cases will metastasize. A small number of similar cases have been reported by other authors [19,24,41,46,59,65,71].

In the present paper a series of eighty-five giant-cell tumors studied in the course of the last twenty years are reviewed. On the services where these tumors were treated, the treatment of choice for a giant-cell tumor is segmental resection, followed by massive bone grafts [96]. This procedure has made possible the gross examination of the complete tumor in a great number of cases (forty-one), most of them unchanged by previous treatment. A great part of this material was received fresh or under conditions of preservation which allowed tissue cultures to be carried out in some cases, as well as a systematic histochemical study. Early in this investigation we studied the acid mucopolysaccharides, glycogen, lipids, and alkaline phosphatase [78], and later studied the acid phosphatase [81,82], and more recently, the beta-glucuronidase [8] and succinic dehydrogenase [84]. The results of these studies in normal bone during ossification were compared with those in a large series of pathological processes characterized by bone reabsorption and remodeling or by the presence of giant cells of the osteoclastic and chondroclastic types. Intense enzymatic activity of acid phosphatase, beta-glucuronidase, and succinic dehydrogenase with no evidence of alkaline-phosphatase activity was regularly demonstrated in the normal chondroclastic and osteoclastic cells. The multinucleated giant cells of the giant-cell tumor of bone and of the so-called variants exhibited identical histochemical behavior. Thus, it seems evident that the histogenetic and physiological characteristics of these different cells are similar in many respects.

There have been very few histochemical studies of giant-cell tumors. The phosphatases were investigated by Gomori [27,28,29], Changus (cited by Boyd [5]), Gilmer [25], and Pepler [69]. Non-specific esterases were studied by Pepler in a limited number of giant-cell tumors, but the results were contradictory. Pais and Baruffaldi [67] investigated the polysaccharides, alkaline phosphatase, lipases, and beta-glucuronidase in fifteen giant-cell tumors and compared the results in these tumors with those in the osteoclastic elements of normal tissue and of certain pathological tissues, including tissues containing tuberculous and foreign-body giant cells.

The extensive histochemical studies on the series of giant-cell tumors reviewed here may serve to clarify some of the disputed aspects of the histogenesis and behavior of this tumor.

MATERIAL AND TECHNIQUE

This series, which includes all cases studied up to January 1959, consists of eighty-five true giant-cell tumors of bone. Reports of forty-six of them were published previously in 1951 [87]. At that time fifty-seven cases were reported but on careful re-evaluation eleven were reclassified as so-called variants.

In many cases abundant material for histopathological study was available from tissue obtained at surgical biopsy or curettage. In forty-one cases the complete specimen was available since thirty-five segmental resections and six amputations had been performed. The amputations had been performed in the earlier cases. In forty-eight of the eighty-five cases, aspiration biopsy had been performed before the tumor was explored surgically. The diagnoses, based on the aspiration biopsy, were proved to be correct in the vast majority of cases. Smears of the aspirated material were stained with hematoxylin and eosin and with the May

Grünwald-Giemsa technique. The remainder of the material was embedded in paraffin—thus permitting a comparative cytological and histological study of the lesion [76].

In addition to the ordinary staining techniques used on the surgical material fixed in 10 per cent formalin and embedded in paraffin, Del Rio Hortega's silver method for reticular fibers and occasionally that for reticulo-endothelial elements were used on frozen sections.

For histochemical study, fresh material was used which had been fixed in 10 per cent formalin, or neutral formalin, and in 80 per cent alcohol (both at 5 degrees centigrade) as well as in Rossmann's fluid.

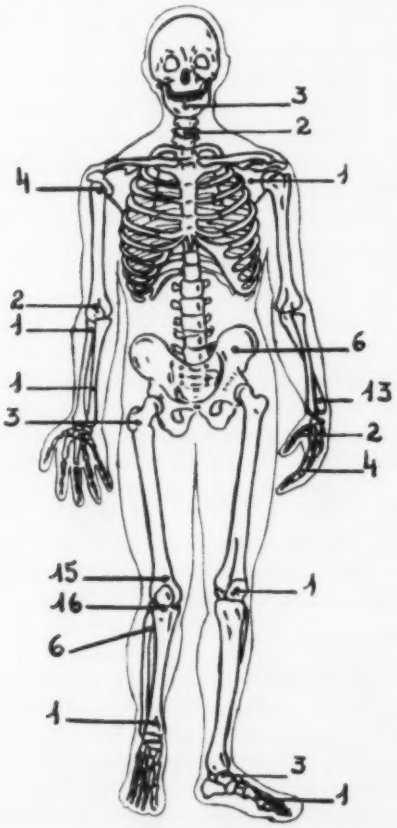

FIG. 1

Skeletal distribution of eighty-five cases of giant-cell tumor.

Glycogen, mucoproteins, acid mucopolysaccharides, lipids, and alkaline phosphatase were investigated in thirty-two cases, acid phosphatase in eighteen, beta-glucuronidase in ten cases, and succinic dehydrogenase in the last six.

Glycogen and mucoproteins were stained by McManus or Hotchkiss periodic acid-Schiff technique after fixation in 80 per cent alcohol at 5 degrees centigrade and in Rossmann's fluid. These preparations were controlled by ptyalin digestion at 37 degrees centigrade for two to three hours or by exposure to takadiastase at room temperature for from one-half to one hour. Lipids were studied using Sudan

IV and Sudan black B on frozen sections. Acid mucopolysaccharides were stained by the Lison-Sylvén method (0.5 per cent toluidine blue), by Hale's colloidal iron method, and by alcian blue (at pH 2.7) according to Mowry's modification [58].

Alkaline phosphatase was demonstrated by Gomori's technique [78], using different incubation periods (ten minutes, thirty minutes, three hours, and twenty-four hours) at pH 9.2. Acid phosphatase was studied in eighteen cases on frozen sections of tissue fixed in neutral formalin at 5 degrees centigrade, using Gomori's technique [28]. For comparison, eight cases were studied with Burton's azo-dye coupling method [7]. Times of incubation varied between five minutes and twenty-four hours.

Fishman and Baker's method [22] was used to demonstrate beta-glucuronidase. This method uses 8 hydroxyquinoline-glucuronic acid as a substrate and can be prepared biosynthetically at low cost.

The histochemical distribution of succinic dehydrogenase was studied by Rosa and Velardo's technique [70], which uses neotetrazolium chloride on fresh, unfixed, frozen sections (twenty to fifty micra thick). In some recent cases the new nitro-blue tetrazolium technique of Nachlas and his associates [61] was used. This technique provides a better visualization of the sites of enzymatic activity in thinner tissue sections under aerobic conditions, after relatively short incubation periods.

A large number (seventeen) of the so-called variants of the giant-cell tumor, aneurysmal bone cysts (six), epiphyseal chondroblastomata (two), chondromyxoid fibromata (one), and non-osteogenic fibromata (eight) were also studied with the same histochemical techniques, as well as solitary bone cysts (eighteen), benign osteoblastomata (two), and giant-cell tumors of the synovial membrane (twenty-three). The results obtained in this material and in the experimental foreign-body granulomata which are now being studied in collaboration with Dr. Cabrini will be the subject of a future publication.

CLINICAL CHARACTERISTICS

It is not the purpose of this paper to present in detail the clinical and roentgenographic features of this tumor. Only a few data concerning the age incidence and the location of the tumor in this series will be given.

Age Incidence

Fifty-eight cases (68 per cent) occurred in patients between twenty and forty years of age; the largest number (thirty-seven) occurred in patients during the third decade, which agrees with the statistics of the majority of authors [12,14,38,48,59,99]. Only nine patients were between the ages of fifteen and twenty years, and none was under fifteen. These authors also noted that giant-cell tumors are rarely found in adolescents and children. In a series of 101 cases Williams and his associates [99] found only ten cases in young people between ten and twenty years and none in patients under ten years; the youngest patient in the series reported by Coley, Higinbotham, and Kogure [14] was eleven years old, and Jaffe [38] mentions an exceptional case of a ten-year-old child.

It is noticeable that some European authors [26], and especially the French [31,94], report a large number of cases of giant-cell tumor in children. Of the eighty-nine cases in Trifaud and associate's series [94], ten were in children under ten years of age and forty-two were in patients younger than twenty years. These figures should be taken with some reservation because from the illustrations published it would appear that several of the tumors represent so-called variants and not true giant-cell tumors. In a recent revision of the material of the Children's Hospital in

Buenos Aires, carried out with Dr. Derqui, fifty tumors or pseudotumors, simulating giant-cell tumors, in children under twelve years were studied and not one case of genuine giant-cell tumor was found.

Localization

As shown in Figure 1 the most frequent site of the giant-cell tumors in this series is the lower epiphysis of the femur (fifteen cases), upper end of the tibia (sixteen cases), and lower end of the radius (thirteen cases). The relative frequency in this series of lesions in the phalanges, metacarpals, and metatarsals (seven cases) is quite remarkable, since these are considered rather rare locations. These tumors are exceptional in the patella and scapula and they are found only very rarely (two cases) in the spine. In this series there were three cases in the mandible. These figures agree with other published statistics [13,14,17,38].

Only a few authors mention multiple sites [13,38,45]. These can only be accepted as giant-cell tumors after hyperparathyroidism has been definitely excluded.

I have seen one patient in whom giant-cell tumor was found in three locations simultaneously—the iliac bone, femur, and tibia. Muscolo and Cabrini [60] reported a case of giant-cell tumor with one focus in the radius and another, which appeared later, in a metacarpal. They considered this to be a metastasis but in my opinion it is probable that this case belongs to this exceptional group of giant-cell tumors with multiple foci.

PATHOLOGICAL ANATOMY

Gross Pathology

The tumor presents, on section, a very characteristic appearance. Although there is considerable variability, all specimens show extensive soft fleshy areas which alternate in color from gray to a light red or dark hemorrhagic hue. The gray zones are of a somewhat firmer consistency, but are friable. The tumor is situated eccentrically in the epiphysis (Fig. 2), extending toward the articular cartilage and toward the metaphysis. In the more advanced stages, these tumors may occupy the whole metaphyseal and epiphyseal region. These extensive tumors are observed usually in the upper extremity, especially in the lower end of the radius. The explanation for this high incidence of extensive tumors in the upper extremity would appear to be that these tumors do not cause symptoms when they are located in non-weight-bearing bones (Fig. 4). As a result patients do not seek medical care until their tumors are far advanced. In the phalanges or metacarpals the tumor may occupy nearly all of the bone (Fig. 4).

The tumor is traversed by thin septa of connective tissue or bone and is surrounded by a thin bone shell which in the more advanced cases is distended beyond the surfaces of the adjacent normal bone as if it were inflated (Figs. 3-A, 3-B, and 5). This thin shell of bone does not represent the expanded cortex. Rather, it is a new displaced cortex formed by osteoclastic absorption of the endosteal surface and constant periosteal-bone deposition, a mechanism which has already been well described by Virchow [97].

In advanced tumors hemorrhage is more abundant, and small bright red or brownish cystic cavities are present. Never found are the large spaces and cystic cavities traversed by thin septa that are seen in aneurysmal bone cysts. Yellowish grey necrotic areas or zones of a sulphur-yellow color typical of xanthoma are often seen in advanced tumors; however, such zones are found only in limited areas and do not constitute a major portion of the lesion, as is the case in a histiocytic xanthogranuloma (non-osteogenic fibroma) which on rare occasions may be located in the epiphysis and simulate a giant-cell tumor roentgenographically (Fig. 7).

FIG. 2

Photograph and roentgenogram of a giant-cell tumor, in the lower end of the femur of a woman, forty-nine years old, localized eccentrically in the epiphysis and the adjacent metaphyseal region. Nine months previously the patient suffered a spontaneous fracture which consolidated after conservative treatment. In the months following, the lesion became evident and after a histological diagnosis of malignant giant-cell tumor was made, an amputation was done. After a review of all the pathological material, the tumor was reclassified as an aggressive giant-cell tumor. (Reproduced with permission from "Tumores a células gigantes de los huesos." By Fritz Schajowicz and S. Mondolfo. Rev. Ortop. y Traumatol., **21**: 3-34, 1951.)

FIG. 3-A

Roentgenograms of a giant-cell tumor, in the upper end of the tibia of a woman, fifty-two years old, which involves the epiphysis and the adjacent shaft. The cortex is expanded, reduced to a thin newly formed bone shell partially destroyed by the tumor.

A giant-cell tumor, even in its more advanced stages, respects the articular cartilage, which is only rarely perforated (Fig. 6). Invasion of the joint space by the tumor is somewhat more frequent by way of the synovial and capsular tissues after the thin newly formed bone cortex has been destroyed. Perforation of the cortex occurs quite often and does not indicate that the tumor is malignant. The margins of the tumor within the metaphyseal spongy tissue are not well defined; there is no delimiting fibrous or bone membrane. This explains the frequency of recurrences after curettage (Fig. 8).

Microscopic Pathology

The histological diagnosis should be based on a study of those areas which have not been modified by extensive hemorrhage and such phenomena as necrosis or cicatricial fibrosis. In well preserved areas the histological structure is characterized by a great number of multinucleated giant cells which are uniformly distributed in the tumor. These cells are irregularly delimited and have prolongations

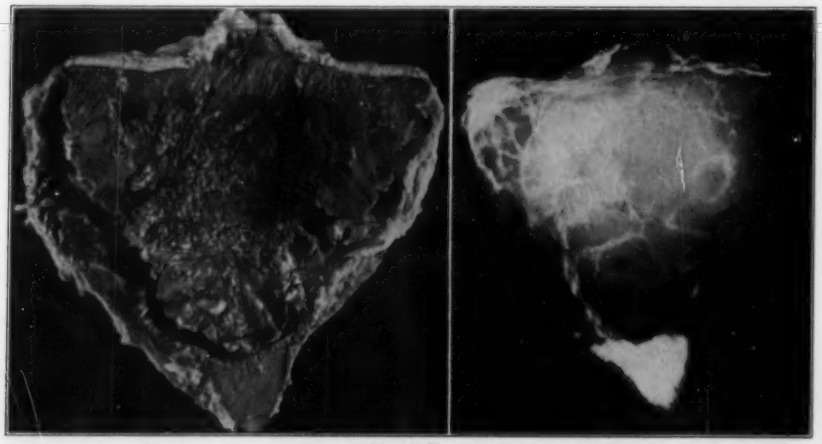

FIG. 3-B

Photograph and roentgenogram of the resected specimen. The large space (visible in photograph) is an artefact.

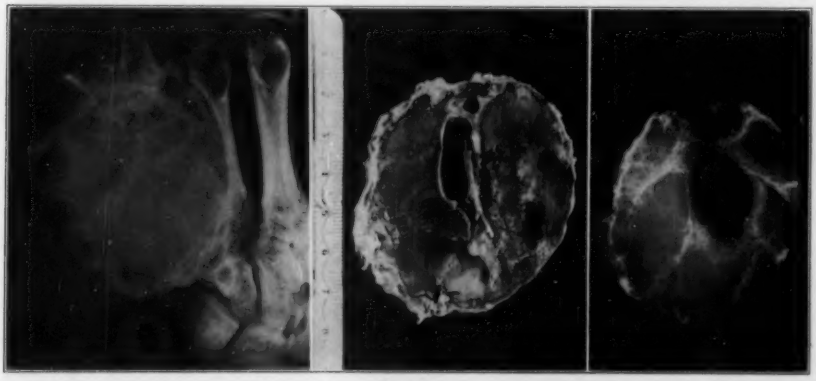

FIG. 4

The roentgenographic and gross pathological appearance of a giant-cell tumor involving the whole extent of the fifth metacarpal of a woman, twenty-two years old. The bone contour is very much distended and the tumor has caused compression atrophy of the adjacent fourth metacarpal bone. The treatment consisted in resection and bone-grafting.

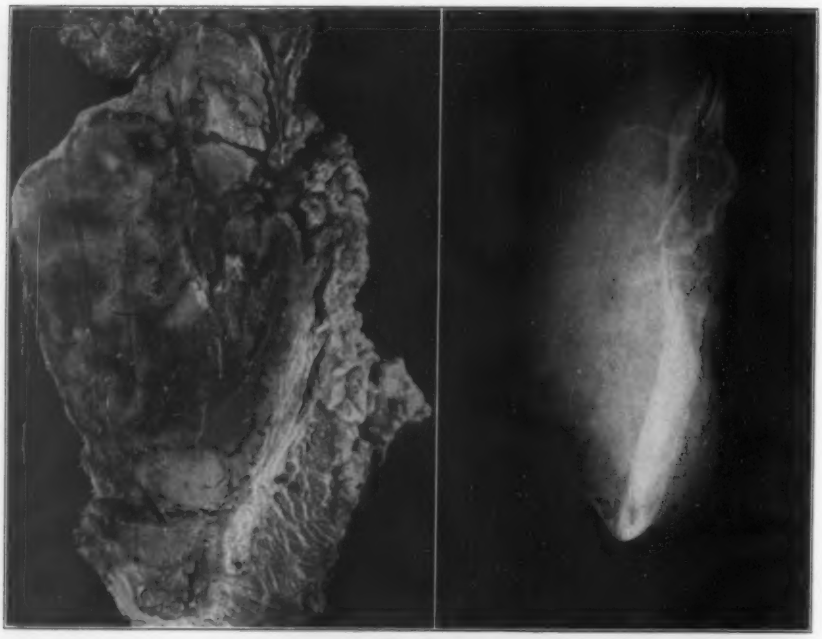

FIG. 5

Photograph and roentgenogram showing the typical aspects of a giant-cell tumor in an exceptional site in the scapula in a thirty-six-year-old man. The bone contour is very much expanded and the newly formed fine bone shell has been destroyed throughout an extensive area.

FIG. 6

Photograph and roentgenogram of the amputation specimen of a very advanced giant-cell tumor in the lower end of the femur in a fifty-two-year-old man. This specimen (histologically not malignant) demonstrates the extension of the lesion with complete destruction of the cortex and a great part of the articular cartilage, with invasion of the joint space after a long period without treatment. (Reproduced with permission from "Tumores a células gigantes de los huesos." By Fritz Schajowicz and S. Mondolfo. Rev. Ortop. y Traumatol., **21**: 3–34, 1951.)

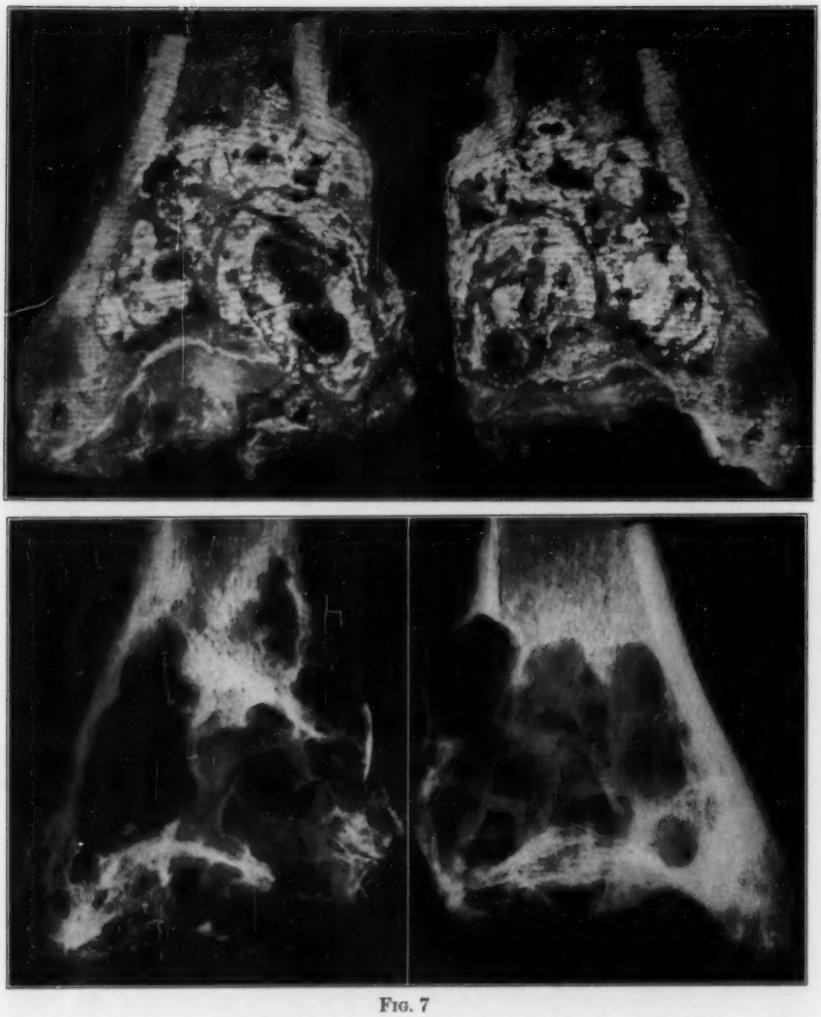

FIG. 7

Photograph and roentgenogram of a recurrent lesion in the distal end of the tibia of a thirty-year-old man. The roentgenographic appearance simulates a giant-cell tumor, but the gross pathological appearance, with predominance of the yellowish xanthomatous tissue and the histological pattern characterized by fibrous tissue, abundant lipoid-bearing foam cells, and sparse giant cells, indicate that it is a histiocytic xanthogranuloma (non-osteogenic fibroma) and not a genuine giant-cell tumor. This lesion had the same microscopic appearance when it was treated by curettage ten years previously.

of their abundant cytoplasm which is more or less basophilic and homogenous, or slightly granular. Sometimes, there are numerous vacuoles of different sizes in the cytoplasm. The size and number of nuclei are variable, but usually there are more than fifteen to twenty, and there may be hundreds. The appearance of the nuclei is identical to that of the nuclei of the mononuclear stromal cells which constitute the other essential element of the tumor. These cells are round, oval, or fusiform in shape and generally have large nuclei with little chromatin and only one or two inconspicuous nucleoli; there are only a few typical mitoses to be found (Figs. 9-A, 9-B, and 9-C).

FIG. 8

Photomicrograph at low magnification, showing the destruction of the bone cortex *a* and the extension of the tumor into the extra-osseous tissues and into the marrow spaces *b*, *b'*. In the marrow spaces there is no bone or fibrous membrane. This explains the frequency of the recurrences after curettage. (Reproduced with permission from "Tumores a células gigantes de los huesos." By Fritz Schajowicz and S. Mondolfo. Rev. Ortop. y Traumatol., **21**: 3–34, 1951.)

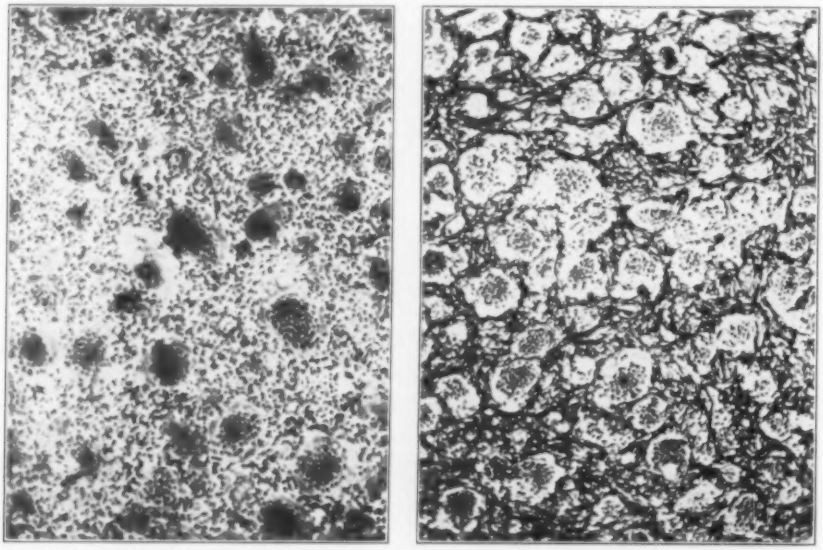

FIG. 9-A FIG. 9-B

Photomicrographs (Fig. 9-A, × 70; Fig. 9-C, × 440) showing the characteristic histological pattern of a giant-cell tumor, with numerous multinucleated cells, the nuclei of which have a great similarity to those of the mononuclear stromal cells (hematoxylin and eosin).

Fig. 9-B: Reticulum stained with Del Rio Hortega's silver-impregnation technique. Numerous reticulin fibers, forming a dense network, surround individual cells and encircle the giant cells (× 70).

With the usual staining technique, the tumor shows very little collagenous stroma in the zones of active growth; nevertheless, with silver stains, a very dense network of reticular fibrils is seen surrounding the individual cells without pene-

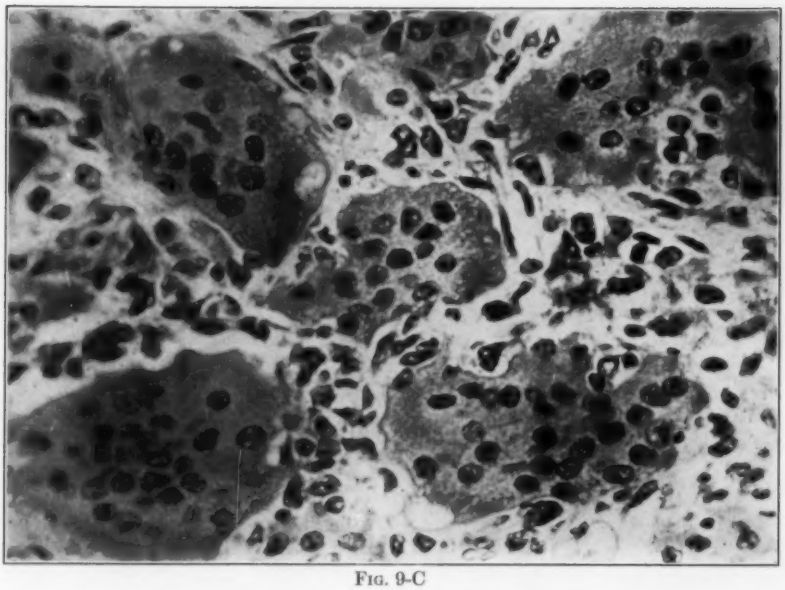

FIG. 9-C

trating the giant cells (Fig. 9-B). The tumor is rich in newly formed blood vessels, with walls composed only of endothelial cells, and in vascular channels which are lined by tumor cells themselves or by an endothelial layer. This vascular pattern would explain the presence of abundant hemorrhages, both recent and old, with phagocytosis of blood pigment by the mononuclear cells of the stroma. In all tumors there are some areas which are composed of spindle cells of a fibroblastic type with abundant intercellular collagenous substance; occasionally, groups of lipoid-bearing foam cells (xanthomatous cells) are present, particularly in the vicinity of necrotic foci. In these areas the giant cells are moderate in size and few in number, or there are none at all. According to Jaffe [38], this pattern reflects spontaneous regression and healing in the tumor. In an occasional giant-cell tumor this healing reaction may be predominant over the characteristic tissue, a histological pattern which indicates a favorable prognosis, as proposed by Scaglietti and Mondolfo [73] many years ago. Several epiphyseal lesions have been observed in which the whole specimen showed this fibroxanthomatous portion with only scattered giant cells. These cases were interpreted as examples of histiocytic xanthomatous granuloma or non-osteogenic fibroma [39,86,87]. They have a naturally favorable prognosis and do not constitute a healing reaction in a genuine giant-cell tumor. One of our cases showed the same predominant fibroxanthomatous appearance, both macroscopically and microscopically (Fig. 7) when the tumor recurred ten years after curettage.

The collagenous septa, of variable thickness, which traverse the tumor, frequently contain trabeculae of reactive new bone. I have not seen any convincing evidence of new-bone formation by the mononuclear tumor cells [59,88,99].

Histochemical Studies

1. *Enzymes*

In the giant-cell tumors there was intense alkaline-phosphatase activity, which was confined to the vessels (Fig. 11-A, *a*). The multinucleated giant cells (Fig. 11-A, *d*) and the mononuclear stromal cells did not contain alkaline phos-

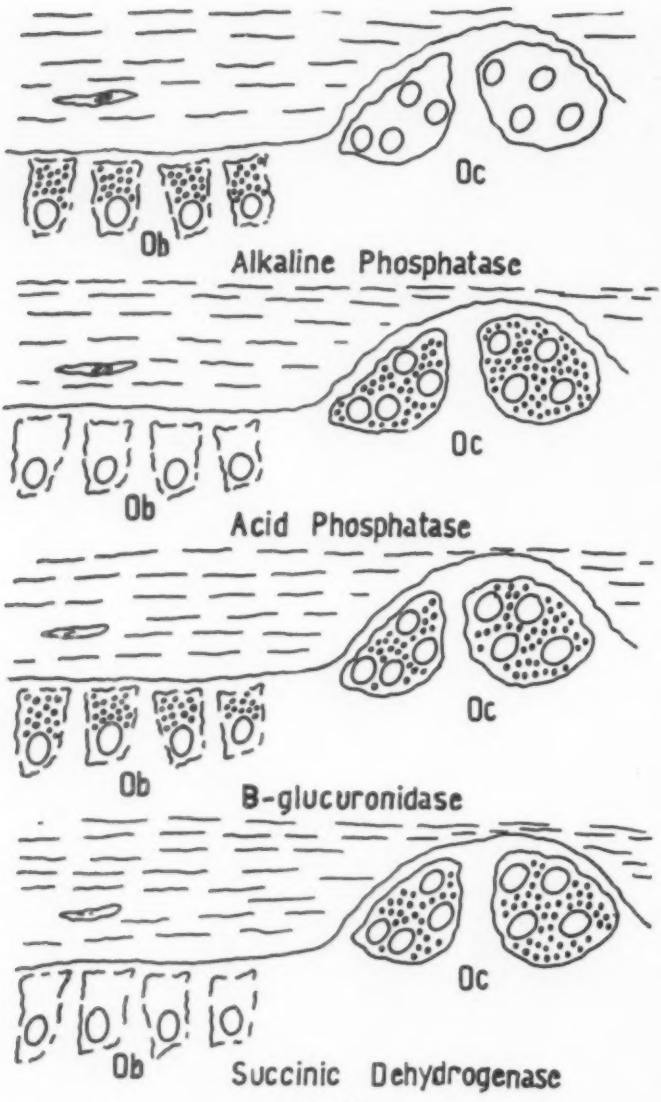

FIG. 10

Schematic drawing showing the intracellular distribution of different enzymes during normal bone formation and destruction. Osteoblasts: *Ob;* and Osteoclasts: *Oc.* Enzyme activity is represented by black dots.

phatase, in contrast to the highly positive osteoblasts surrounding the new-formed subperiosteal bone trabeculae (Fig. 11-B, *b*). The osteoclastic giant cells showed no activity (Fig. 11-B, *d*).

The multinucleated giant cells exhibited a strong acid-phosphatase activity which appeared after five to ten minutes of incubation, whereas the mononucleated cells only commenced to react after more than three hours' incubation.

Topographically, the results obtained by Gomori's method and Burton's azo-dye technique are identical, but the two techniques showed differences in

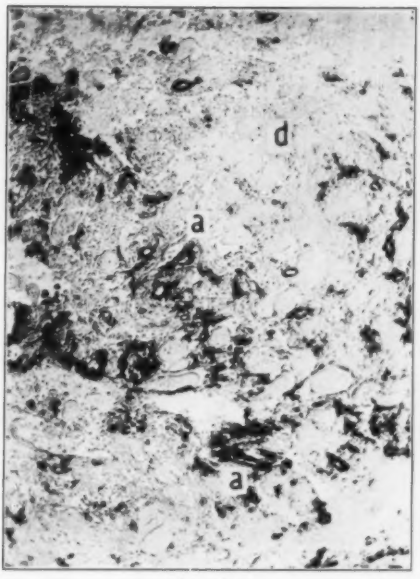

FIG. 11-A

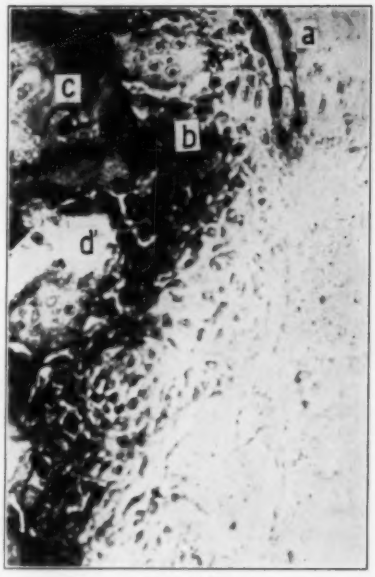

FIG. 11-B

Giant-cell tumor of the femur stained for alkaline phosphatase (Gomori's technique, incubation time, thirty minutes). The enzyme is localized in the blood vessels *a*, osteoblasts *b*, and some young cells included in the trabeculae *c*. The multinucleated giant cells of the tumor *d* and the osteoclasts *d'* are lacking in enzyme (Fig. 11-A, × 80; Fig. 11-B × 360).

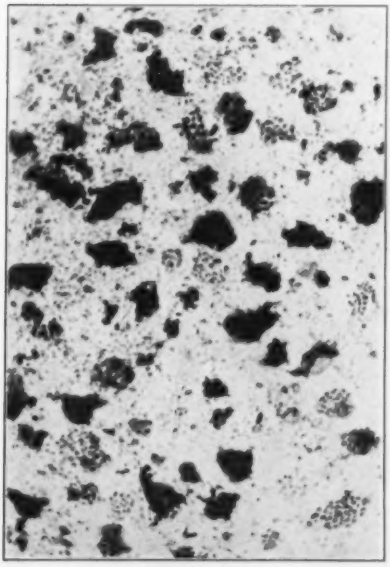

FIG. 12-A

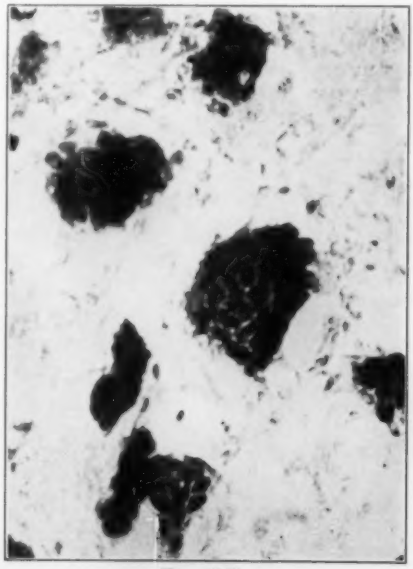

FIG. 12-B

Giant-cell tumor of tibia stained for acid phosphatase (Gomori's technique, frozen section, incubation time, thirty minutes: Fig. 12-A, × 175; Fig. 12-B, × 345). Intense enzymatic activity is observed in the multinucleated giant cells localized predominantly in the nuclei; it is lacking in the mononuclear stromal cells.

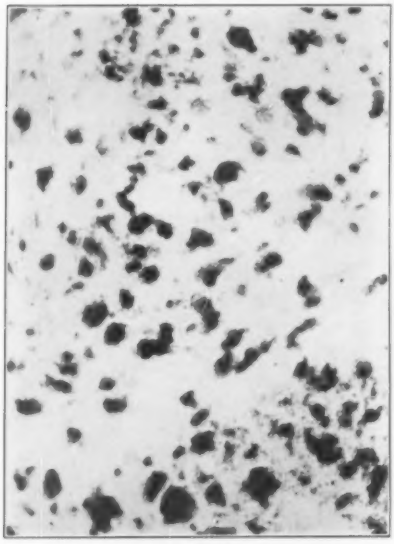

FIG. 13-A

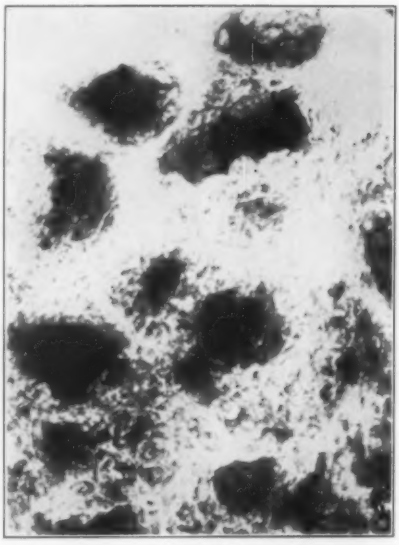

FIG. 13-B

Giant-cell tumor of femur stained for acid phosphatase (Burton's azo-dye technique, frozen section, incubation time, two hours: Fig. 13-A, × 75; Fig. 13-B, × 345). Intense enzymatic activity is shown, localized predominantly in the cytoplasm of the giant cells.

cytological details. Gomori's method gave predominantly nuclear images (Figs. 12-A and 12-B), whereas Burton's azo-dye coupling method showed staining of the cellular cytoplasm, the nuclei remaining almost negative (Figs. 13-A and 13-B).

Burton's method gave precipitates after incubation for several hours; this makes it very difficult to detect small amounts of enzymatic activity.

The multinucleated giant cells present in aneurysmal bone cysts (Fig. 14)

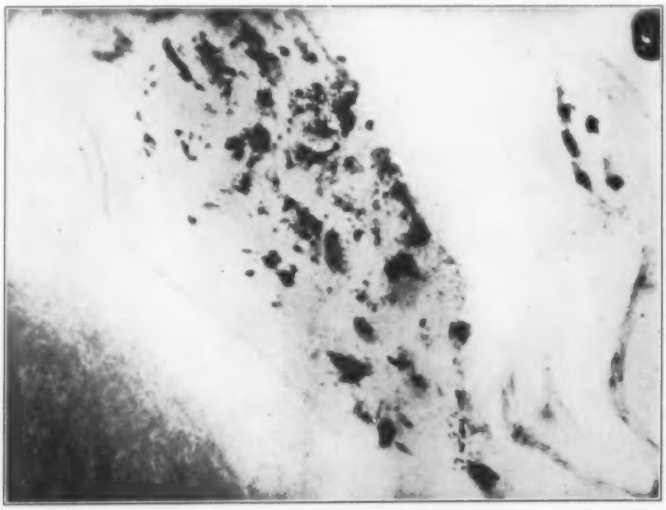

FIG. 14

Aneurysmal bone cyst stained for acid phosphatase (Gomori's technique, frozen section, incubation time, one hour, × 90). Strong enzymatic activity is observed in the numerous giant cells of different sizes present in the septae surrounding the blood spaces.

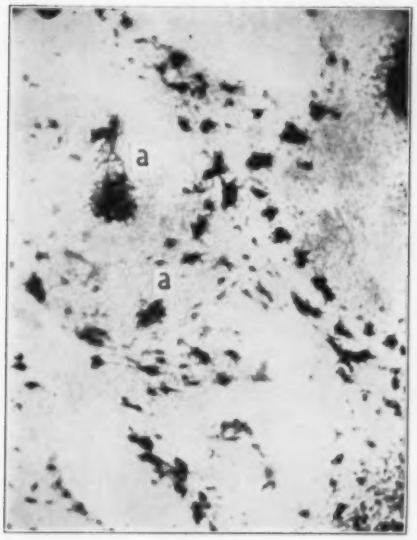

FIG. 15-A

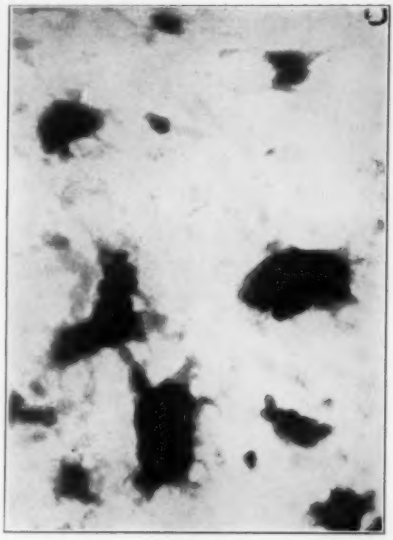

FIG. 15-B

Osteogenic sarcoma of humerus stained for acid phosphatase (Gomori's technique, frozen section, incubation time, thirty minutes: Fig. 15-A, × 73; Fig. 15-B, × 310). Intense activity in the numerous multinucleated giant cells of osteoclastic type is observed. Some calcified bone trabeculae also appear black, *a*.

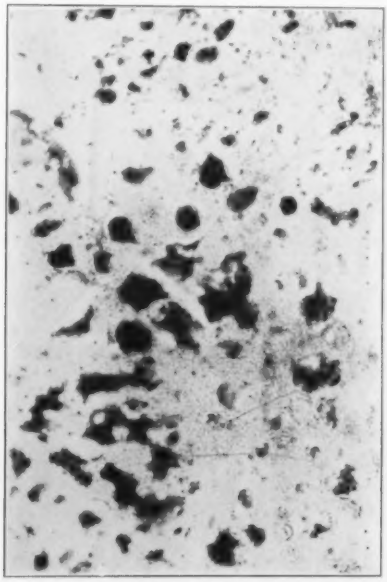

FIG. 16-A

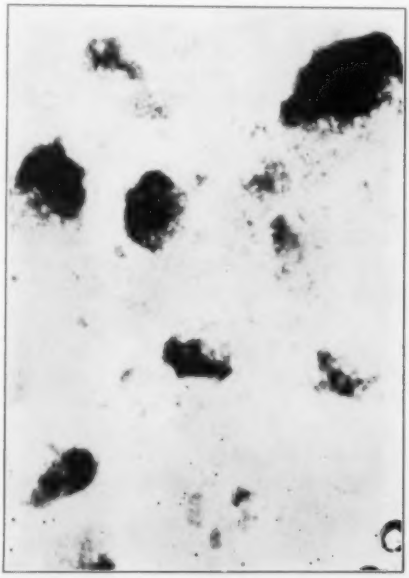

FIG. 16-B

Giant-cell tumor of tibia stained for beta glucuronidase (Fishman and Baker's technique, frozen section, incubation time, one hour: Fig. 16-A, × 80; Fig. 16-B, × 360). The enzymatic activity is localized, especially in the cytoplasm of the multinucleated giant cells in different stages of evolution.

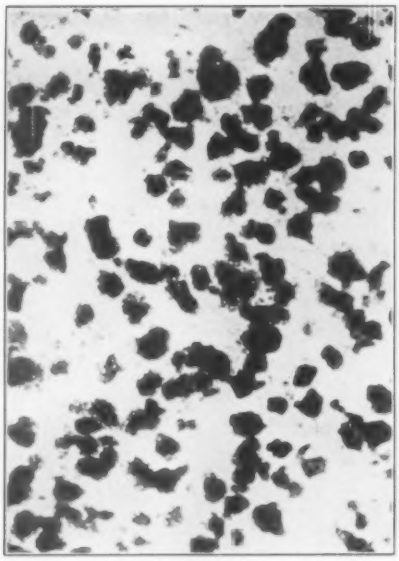

FIG. 17-A

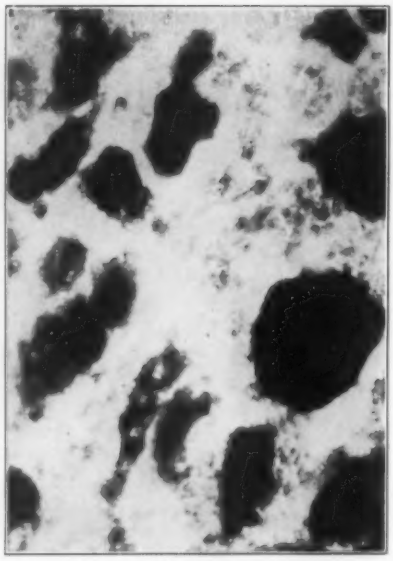

FIG. 17-B

Giant-cell tumor of tibia stained for succinic dehydrogenase (nitro-tetrazolium technique of Nachlas and associates, incubation time, thirty minutes: Fig. 17-A, × 75; Fig. 17-B, × 340). Strong enzymatic activity is localized, especially in the cytoplasm of the giant cells, the nuclei appearing as blank discs.

epiphyseal chondroblastoma, non-osteogenic fibroma, fibrous dysplasia, Paget's disease, solitary bone cysts, osteogenic sarcoma (Figs. 15-A and 15-B), and the like, also reacted very intensely, but I have not, as yet, established whether any quantitative difference exists.

In fourteen cases of pigmented villonodular synovitis, a positive reaction was observed in the multinucleated giant cells, but this activity seemed to be somewhat weaker than in the other lesions studied.

An abundant quantity of beta-glucuronidase which appears as a compact mass of blue granules in the cytoplasm was demonstrated in the giant cells after thirty minutes of incubation, while the nuclei remain negative (Figs. 16-A and 16-B). The enzymatic activity in mononuclear cells was much less, appeared as a weak reaction after three hours, and became somewhat more intense at twenty-four hours, although it never reacted with the same intensity as in the giant cells.

Intense succinic-dehydrogenase activity was observed after short incubations (ten to thirty minutes) in the giant cells of the six tumors studied; the activity was located primarily in the cytoplasm. The mononuclear cells did not show any enzymatic activity (Figs. 17-A and 17-B).

A case of osteogenic sarcoma also showed intense enzymatic reaction in the numerous giant cells of the osteoclastic type present in this tumor. There was only weak or no activity in the other tumor cells (Figs. 18-A and 18-B).

2. *Carbohydrates and Lipids*

With the McManus' method of periodic acid-Schiff staining, most giant cells showed diffuse reddish colored cytoplasm or more often fine reddish granules distributed in an irregular manner, sometimes in one and sometimes in both poles of the cell, and more rarely in the whole cytoplasm, but not in the nucleus (Figs. 19-A and 19-B). The cells of the stroma rarely took the stain. Staining remained after

FIG. 18-A

FIG. 18-B

Osteogenic sarcoma of humerus, stained for succinic dehydrogenase. There is intense enzymatic activity in the multinucleated giant cells of osteoclastic type (nitro-tetrazolium technique, incubation time, one hour). Same case and magnification as Figs. 15-A and 15-B.

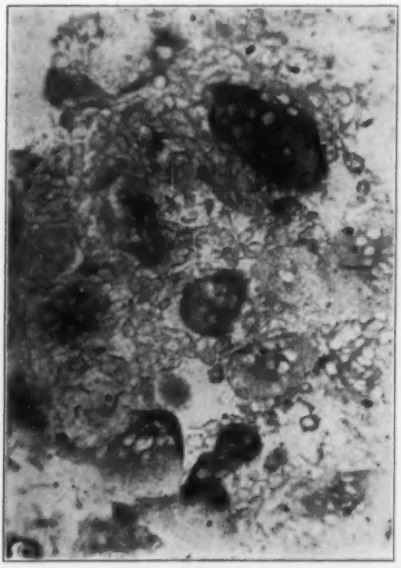

FIG. 19-A

FIG. 19-B

Fig. 19-A: Giant-cell tumor of radius. Periodic acid-Schiff positive substances in different amounts are shown in the cytoplasm of almost all giant cells, appearing as dark stained zones in the photomicrograph. The nuclei appear as blank discs since no counterstain has been used (McManus stain, × 310).

Fig. 19-B: Sudan black-B positive granules are shown in the cytoplasm of the giant cells; the nuclei are unstained (frozen section without nuclear counterstain, × 320).

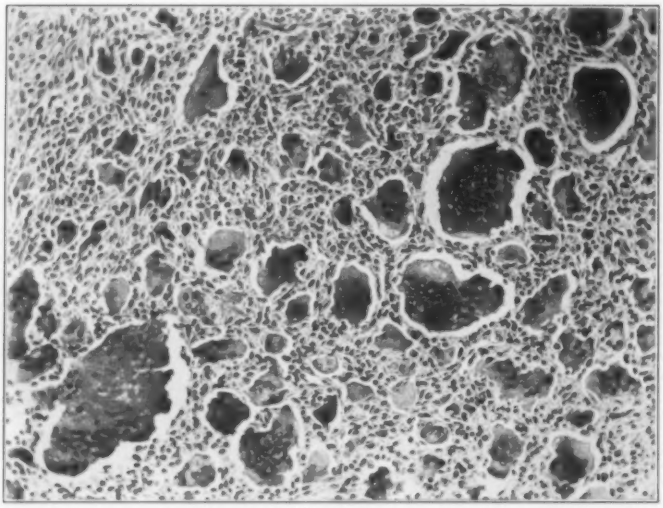

FIG. 20

Giant-cell tumor of tibia. Acid mucopolysaccharides are shown with Mowry's modification of the alcian-blue technique, and appear as diffuse dark-staining zones in the cytoplasm of most giant cells (× 122).

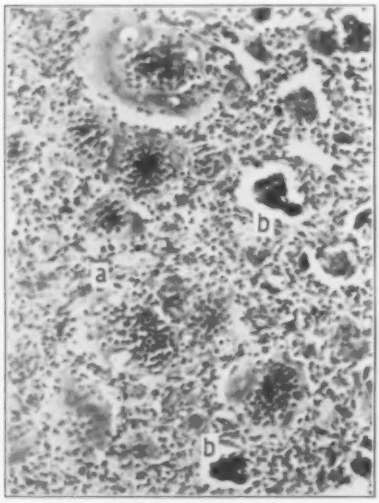

FIG. 21-A

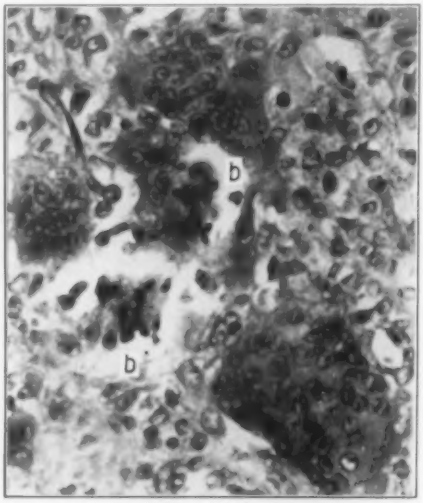

FIG. 21-B

Regressive changes, consisting in vacuolar degeneration of the cytoplasm *a* and pyknosis of the nuclei of the giant cells *b*, are frequently observed in giant-cell tumors (hematoxylin and eosin: Fig. 21-A, × 105; Fig. 21-B, × 390).

digestion with ptyalin and takadiastase, proving that it is not glycogen but some other type of carbohydrate.

The results with metachromatic staining with toluidine blue were not very clear as the basophilia of the cytoplasm of the giant cells impeded the demonstration of discrete metachromasia. Nevertheless, by use of alcian blue 8 GS (pH 2.7) with a short staining time and in acid solution, a technique which appears to be selective for acid mucopolysaccharides, a pale blue color was seen in the cytoplasm

FIG. 22-A

FIG. 22-B

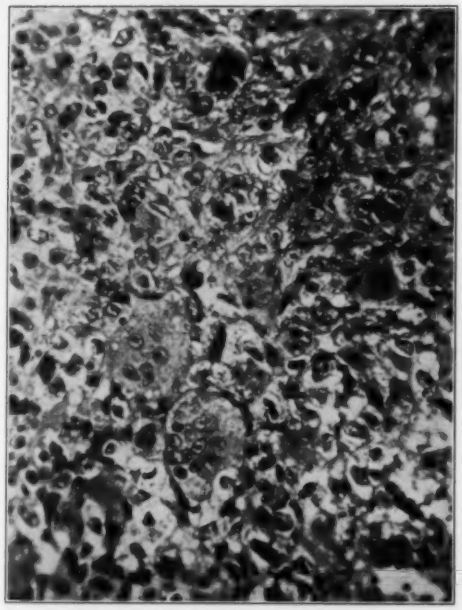

FIG. 22-C

Malignant giant-cell tumor of the proximal part of the tibia. The specimen shows the grayish color of the tumor; the dark zone corresponds to a local hemorrhage in the tract of an aspiration biopsy. The photomicrograph shows the sparsity and smaller size of the giant cells and the polymorphism of the numerous stromal cells. The nineteen-year-old patient was treated with resection of the upper end of the tibia followed by bone-grafting and arthrodesis of the knee. She was alive twelve years later.

of many of the giant cells. The distribution of the cytoplasmic staining was irregular and, like periodic acid-Schiff, generally more intense in the cell poles. Only rarely was a positive reaction obtained within the stromal cells (Fig. 20).

Material stained with Hale's colloidal-iron technique showed a similar distribution with positive staining of the giant cells, primarily their cytoplasm, and almost complete absence of staining in the stromal cells. The specificity of this method is not yet clearly defined and it is probable that proteins and mucoproteins give positive staining reactions, as well as the acid mucopolysaccharides [49,68].

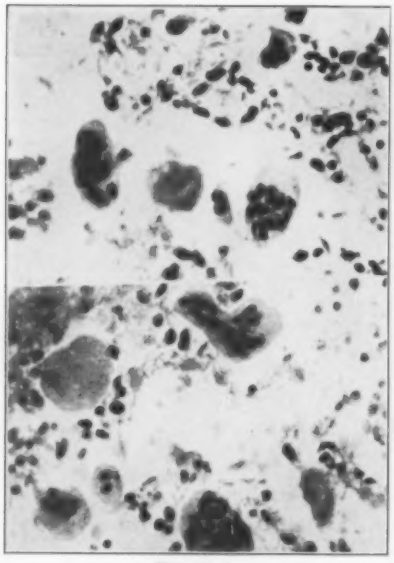

FIG. 23-A

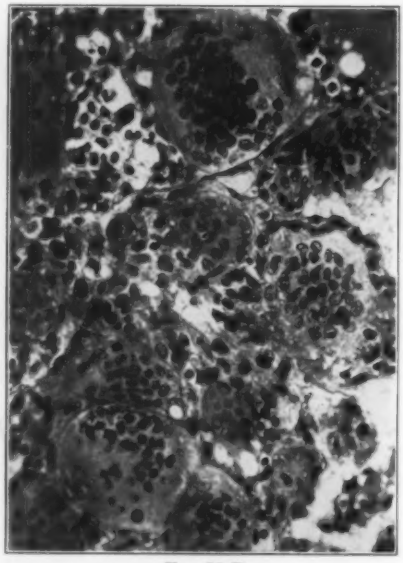

FIG. 23-B

Photomicrograph showing pulmonary (Fig. 23-A, × 275) and subcutaneous (Fig. 23-B, × 345) metastasis of a giant-cell tumor of the lower end of femur in a twenty-nine-year-old woman, treated with curettage and roentgen therapy, followed by resection. Histologically, the appearance is benign. (Fig. 23-A reproduced with permission from "Su di un caso di tumore giganto-cellulare con metastasi". By C. E. Ottolenghi, Fritz Schajowicz, and S. Mondolfo. Arch. "Putti", 4: 111–124, 1954.)

Only rarely was positive staining of the giant cells observed in formol-fixed frozen sections, stained with Sudan IV. This reaction was more frequent in the mononuclear cells, especially the foam cells adjacent to necrotic foci. In frozen sections stained with Sudan black B nearly all the giant cells presented an abundance of small granules which were distributed both diffusely and irregularly in all the cytoplasm, often being more intense in the vicinity of the cell poles (Fig. 19-B). The reaction is much less or absent in paraffin-embedded material. The mononuclear cells, which are positive to the Sudan IV method, present an intense bluish black coloring, which disappears entirely in paraffin-embedded material.

The presence in the cytoplasm of giant cells of substances which are positive to periodic acid-Schiff and Sudan black B and negative to Sudan IV indicates the existence of complex lipids, probably glycolipids (cerebrosides) or phospholipids. I have observed very similar histochemical reactions in Gaucher cells which contain cerebrosides of the abnormal kerasin type [63].

Histogenesis

Only a very few modern authors [98] still accept regeneration or inflammatory hyperplasia as the etiology of giant-cell tumor. This explanation was proposed a long time ago, especially by Looser [50], Konjetzny [44,45], and Haselhofer [34] in Germany, and by Barrie [3] in the United States.

I agree with the majority of authors that the giant-cell tumor is a neoplastic process and that the origin of the mononuclear stromal cell is from the undifferentiated mesenchymal cells of the bone marrow, interpreted by some authors as reticulohistiocytic elements.

From these same immature mesenchymal cells, with their tendency toward

fibroblastic differentiation, come the multinucleated giant cells, either by agglutination or conglomeration of the stromal cells, as held by the majority of authors [1,17,23,24,47,48,57,99,100] or by repeated division of the stromal-cell nucleus with-

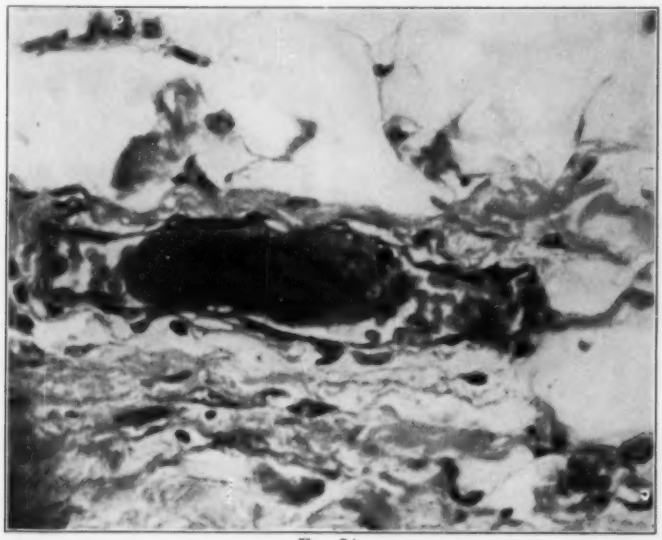

FIG. 24

A multinucleated giant cell is observed in a capillary blood vessel of the parosteal fibro-adipose tissue, adjacent to a giant-cell tumor.

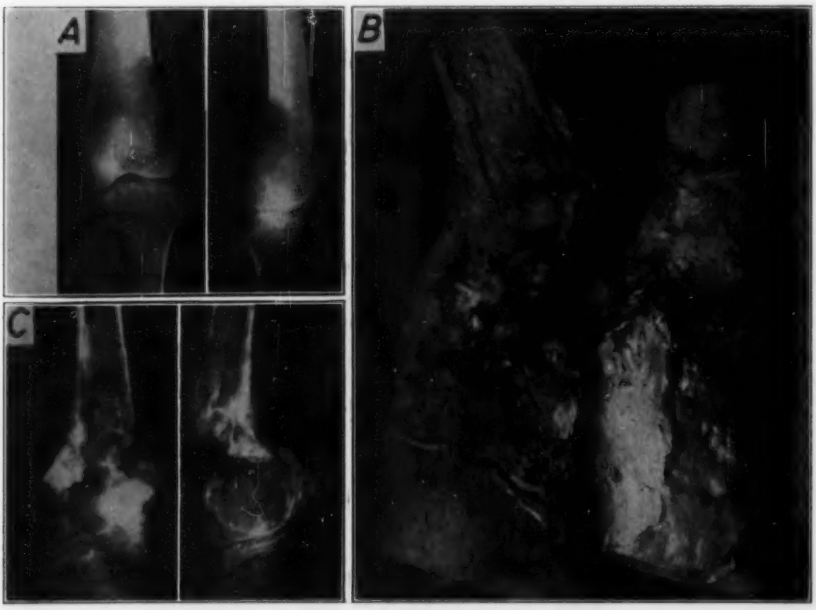

FIG. 25

Sarcomatous transformation of a benign giant-cell tumor of the lower end of the femur, eighteen years after curettage and roentgen therapy in a twenty-year-old woman. *A:* roentgenogram of July 1938 before treatment; *B* and *C:* roentgenogram and photograph of the amputation specimen (Case of Dr. I. Slullitel). The patient died six months later with pulmonary metastases.

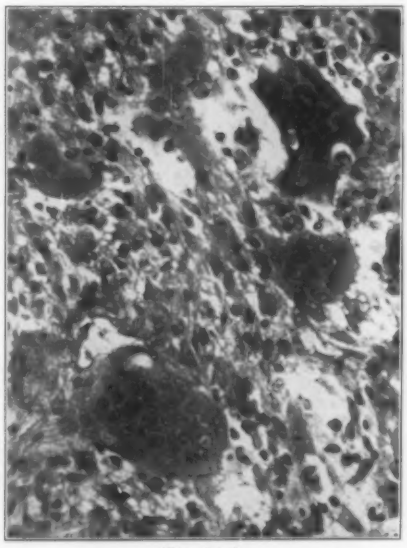

FIG. 26-A

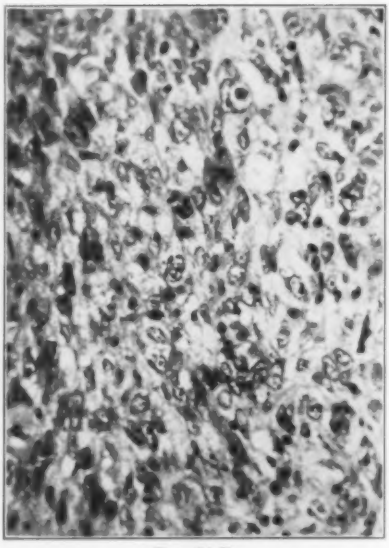

FIG. 26-B

Figs. 26-A, 26-B, and 26-C: Microphotographs of the same case as Fig. 25, showing in Fig. 26-A (× 330) the characteristic microscopic pattern of a benign giant-cell tumor before treatment and the appearance eighteen years later, after sarcomatous changes had appeared. In Fig. 26-B (× 330) the histological appearance is that of a fibrosarcoma but in Fig. 26-C (× 450) some scattered multinucleated giant cells of moderate size are still present. Atypical mitoses are frequent (hematoxylin and eosin).

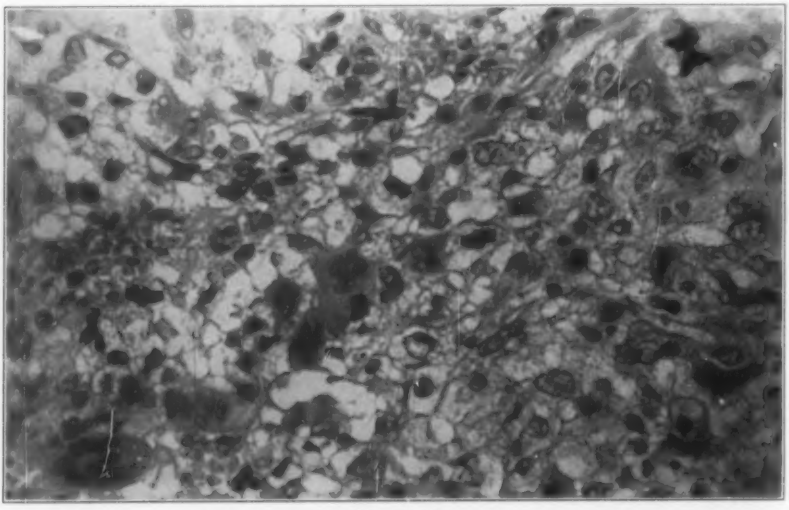

FIG. 26-C

out the corresponding cytoplasmic division, as suspected by Virchow [97] and reiterated by von Albertini [2]. Studying the cytological details of smears from numerous giant-cell tumors and tissue cultures Lustig and I [51] have been able to prove the existence of this last mechanism. Although we could not define the exact details of the cellular division, it seems to be amitotic. Brachetto-Brian [6] confirmed this finding in a solitary bone cyst.

In a systematic study now in progress with Montes de Oca and Cabrini, tissue cultures from forty cases of different types of bone tumor are being grown. Four of these are giant-cell tumors and in these we have observed a series of fields which would apparently indicate that the giant cell is formed by division of a mononucleated cell of the fibroblastic type, either by amitotic division or, as we have observed with great frequency, by nuclear segmentation. These findings must be confirmed by the study of more extensive material in order to exclude the possibility of their being degenerative cellular phenomena related to the type of culture medium used [56].

Owing to the great resemblance between the histochemical behavior of the osteoclast and the giant cell, the giant cell can be considered as a neoplastic deviation of the osteoclast. This would explain certain morphological differences between the two, such as the larger size and greater number of nuclei of the giant cell and the great abundance of these cells in a giant-cell tumor which far surpasses any functional requirement.

For these reasons I do not oppose the designation *osteoclastoma*, which has been used by most British authors from Stewart [91] to the present time. It seems quite clear that the multinucleated giant cell of the giant-cell tumor belongs to the same family as the normal osteoclast and that, even though it is a neoplastic element, it would be expected to exhibit a bone-destroying function.

Until these new findings are confirmed and the histogenesis of this tumor better defined, I shall continue to use the neutral term *giant-cell tumor of bone*.

The giant cell appears to have a limited life span, for in tissue cultures degenerative phenomena appear after three days while the fundamental mononuclear cell is still actively growing. These regressive changes are also often seen in histological specimens of giant-cell tumors and consist of nuclear pyknosis and karyorrhexis or karyolysis, which are generally combined with vacuolar degeneration of the cytoplasm (Figs. 21-A and 21-B). These phenomena correspond to different phases of the involutional cycle of the giant cell and were described in detail by us in 1943 [85] and by Brachetto-Brian [6] in 1946.

CLINICAL-HISTOLOGICAL CORRELATION

A careful histopathological review of our material and correlation of these findings with the clinical features of our cases showed that even in the cases with no previous treatment variations of the histological pattern exist, characterized principally by a more or less active proliferation of the mononuclear stromal cells. However, I believe that only striking histological evidence of malignancy can be considered of prognostic value (Jaffe and Lichtenstein's Grade III). Evidence of malignancy is a pronounced atypism of the stromal cells with frequent typical mitoses, often accompanied by atypical mitoses, and generally a diminution in the size and number of the giant cells.

These exceptional cases of which there were three in our series, have a more rapid evolution, a greater recurrence rate, and a greater frequency of metastasis, all of which agree with their ominous histological appearance. They should not be confused with osteolytic osteogenic sarcoma. The presence of areas showing neoplastic new-bone formation, sometimes difficult to perceive with the usual histological techniques but easily demonstrated by the presence of intense alkaline-phosphatase activity, makes differentiation of the two processes possible.

In benign (Grade I) and aggressive (Grade II) forms, no exact correlation exists between the histological picture and the clinical evolution, although it is perhaps more common for the histologically aggressive tumor to grow more rapidly, to be more destructive, and to be more apt to recur. On the other hand,

both types of histological pattern, as well as intermediate stages, may exist in different areas of the same tumor and pulmonary, bone, and cutaneous metastases of the same type may occur in both benign and aggressive tumors, as was observed in one of our cases (Figs. 23-A and 23-B) and has been described in the literature.

This complication may be explained in part by the fact that giant cells and small groups of tumor cells are often found in blood vessels near the tumor [6,38,85,89] (Fig. 24).

Sarcomatous Transformation

It is an indisputable fact that a benign giant-cell tumor may transform into a sarcoma. This generally occurs after roentgen therapy, whether associated with conservative surgical intervention or not. A considerable number of such cases have been published in detail. This complication occurs in about 10 per cent of cases [9] although some statistics [38,93] go as high as 15 per cent.

In this series, six cases of sarcomatous transformation occurred and all had been previously treated with roentgen therapy alone or in combination with curettage. The majority (five) of the sarcomata were fibrosarcomata. This agrees with other published cases, which include only very few osteogenic sarcomata [10,16,72].

The interval between commencement of roentgen therapy and the appearance of sarcoma has generally been between five and eight years; in our series it was between three and eighteen years, but other authors [10,16,38] mention cases in which the sarcoma appeared twenty-two and twenty-three years after roentgen therapy. Whether the action of the roentgen rays on the tumor cells is the cause of this late transformation, due to biological changes in the stromal cell, demonstrable as cytological changes [74], or whether it is the harmful effect of irradiation on neighboring healthy tissue [35], is still an unsolved problem.

The finding in one of our cases of fibrosarcomatous areas alongside areas showing the histological pattern of a malignant giant-cell tumor, and the same findings reported by Jaffe in some of his cases, appear to argue in favor of a true sarcomatous transformation of a pre-existent, apparently benign giant-cell tumor (Fig. 25).

DISCUSSION

It has become evident that the concept held by Nélaton [62], Gross [29], and Bloodgood [4] that the giant-cell tumor is a uniformly benign lesion is no longer valid. The estimation of different degrees of malignancy, although of use in some cases, has lost a great part of its value during recent years, since it is now known that with the exception of the frankly malignant forms, no good correlation exists between the histological picture and the clinical evolution. An increasing number of cases of benign or aggressive giant-cell tumors are being reported which have produced metastases with identical histological patterns. These are the main reasons which led us to resort to a more radical form of therapy, consisting in total resection of the tumor followed by bone-grafting in all instances in which the diagnosis of true giant-cell tumor is positive [96]. We have found no metastases or recurrences in those cases in which an adequate resection was performed as the first treatment. During the last few years an increasing number of surgeons have adopted this form of radical surgery [14,40,53,74].

Therefore, after almost 100 years, we are returning to the concept held by Virchow [97], who, in spite of calling the tumor a myelogenous giant-cell sarcoma (myelogenes Riesenzellsarkom), stated that in the majority of cases when the

tumor is completely removed in time it has such a good prognosis that it can almost be considered benign.

I consider that it is sufficient to make a histological diagnosis of true giant-cell tumor without necessarily giving the exact grade. The diagnosis can be made from an aspiration biopsy which enables material to be obtained from multiple areas. When performed prior to excision of the lesion, aspiration biopsy has given a correct diagnosis in 85 per cent of cases [64,76].

Our histochemical studies indicate that the histochemical behavior of the multinucleated giant cells of the giant-cell tumor and of the normal osteoclasts and chondroclasts is identical. This finding, in our opinion, indicates a close relationship and similarity in the physiological behavior of these cells.

The few papers published on this subject agree that there is a strong reaction for acid phosphatase in the multinucleated giant cells of the true giant-cell tumor, as well as in the giant cells of the so-called variants [5], the granulomatous lesions of tuberculosis, tuberculoid leprosy, and foreign-body reactions [67,69]. But Boyd [5], who bases his assertion on the studies of Changus and Gilmer, which have not been published in detail, also mentions the presence of acid phosphatase in the stromal cells of the giant-cell tumor and its absence in the variants and in other similar bone lesions, such as bone cysts, non-osteogenic fibromata, and fibrous dysplasias. Boyd considers these findings to be of value as a method of differential diagnosis.

Like Gomori, I have found intense acid-phosphatase activity but no alkaline phosphatase in the multinucleated giant cells and no alkaline or acid phosphatase in the stromal cells. Identical results were obtained in the so-called variants of giant-cell tumor and similar lesions. These findings have been confirmed by Pais and Baruffaldi [67]. The alkaline-phosphatase activity described by Boyd [5] in the stroma is due, in my opinion, to areas of reactive or metaplastic osteogenesis which are very common in these lesions. I do not think, therefore, that these histochemical methods can be of any use for diagnostic purposes.

The systematic biochemical studies carried out by Woodard [101] confirmed that the acid-phosphatase content of the giant-cell-tumor tissue is considerably higher than that of most other lesions in the osseous system, but the highest value found was only two units per gram. Since 200 units per gram are often seen in carcinoma of the prostate, it can not be expected that the presence of a giant-cell tumor will cause changes in the serum acid phosphatase comparable to those produced by metastatic prostatic cancer. Nevertheless, Lasser and Tetewsky [46], on two occasions, found in a case of metastasizing giant-cell tumor slightly elevated acid-phosphatase levels in the serum and suggested that these elevated levels may represent an abnormal amount of this enzyme released from the giant cells in the metastatic lesions. This problem requires further study, as other authors have also found a significant increase of acid phosphatase in bone and serum, both in experimental hyperparathyroidism [43], and in humans with the disease [32,42]. When the parathyroid tumor was removed, the serum-acid-phosphatase levels promptly fell to normal, coincident with the fall of the serum calcium, indicating that the serum-acid phosphatase in hyperparathyroidism is derived from an osseous source [22].

Histochemical studies have also shown the presence in giant cells, of the enzymes, beta-glucuronidase and succinic dehydrogenase. The giant cells also contain a periodic acid-Schiff positive substance in their cytoplasm which is either diffuse or finely granulated. This is not glycogen and is positive with Sudan black B and negative with Sudan IV. We have observed similar histochemical reactions, as have others [63] in Gaucher cells. These reactions evidently indicate the presence of complex glycolipids or phospholipids.

The various histochemical reactions for acid mucopolysaccharides did not give consistent results, and those obtained with Hale's colloidal-iron method are of rather questionable significance due to their apparent lack of specificity [49,68]; the metachromatic stain, toluidine blue, gave indefinite results due to the masking effect of the basophilia of the cytoplasm of the giant cells. Far more convincing results were obtained using alcian blue, which stains connective-tissue mucin and most epithelial mucins in acid solutions, with very little staining of the background proteins [58]. Using this technique, fine blue granules were found distributed in the cytoplasm in a very irregular manner in the majority of the giant cells. Differences in quantity of staining of benign and malignant cells, as found by Pais and Baruffaldi [67], could not be proved.

Osteoclasts and chondroclasts showed similar histochemical behavior in both normal and pathological conditions, but so did the giant cells present in pseudoneoplastic processes of the synovial membrane and granulomatous diseases [67,69], which are not related to bone and cartilage resorption.

Although Pepler [69] stated that granulomatous giant cells contain a nonspecific esterase, not present in giant-cell tumors of bone, these differences do not appear to be of fundamental importance.

In our present state of knowledge it would appear that this metabolic and enzymatic activity of the multinucleated giant cells is related to the digestion, solution, and elimination of several classes of substances.

SUMMARY

1. A series of eighty-five cases of giant-cell tumors of bone studied in the course of the last twenty years is reviewed. Comparative clinical, roentgenographic, pathological, and systematic histochemical studies have been carried out.

2. The clinical and pathological findings confirm the necessity of treating these tumors as an entity, because they are neoplastic processes capable of progressive growth, recur in a large percentage of cases, and, in 7 to 15 per cent of cases become transformed into sarcomata. They may produce metastases without visible malignant transformation. The so-called variants, which in general have a favorable prognosis, are easily distinguishable from true giant-cell tumors.

3. With the exception of a few rare cases showing a frankly malignant microscopic structure, there was no evident correlation between the histological appearance and the clinical and roentgenographic features. For this reason, grading of this neoplasm is now considered of little value. It is sufficient to establish a diagnosis of true giant-cell tumor to justify complete resection of the lesion. This diagnosis can be made by aspiration biopsy.

4. I believe that the giant cell derives from the mononuclear cell of the stroma and is thus of mesenchymal origin. I think that it is formed not only by agglutination and conglomeration of these cells, as is maintained by the majority of writers, but also by repeated division of the stromal-cell nuclei, without corresponding cytoplasmic division. This is probably accomplished by amitosis or nuclear segmentation, which has been observed in tissue cultures.

5. Systematic histochemical investigations of normal tissues, true giant-cell tumors, and many bone lesions and extra-osseous lesions, which are characterized by the richness of multinucleated giant cells, were done. The giant cells in these tissues have a very similar histochemical behavior. A close physiological and histogenetic relationship is thus established between normal osteoclastic and chondroclastic giant cells and those of giant-cell tumor.

6. Giant cells are characterized by an abundance of acid phosphatase, beta-glucuronidase, and succinic dehydrogenase; the absence of alkaline phosphatase;

and the presence in their cytoplasm of non-glycogen carbohydrates, principally acid mucopolysaccharides, and complex lipids. The stromal cells of giant-cell tumors do not generally show enzymatic reactions, nor do they possess glycogen, mucopolysaccharides, or glycolipids in significant amounts.

7. Histochemical study is of no diagnostic value when differentiating the giant-cell tumor from its so-called variants.

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Prognosis of Fractures of the Acetabulum*

BY CARTER R. ROWE, M.D., AND J. DRENNAN LOWELL, M.D.,
BOSTON, MASSACHUSETTS

From the Fracture Clinic, Massachusetts General Hospital, Boston

At the present time, there is a pessimistic outlook among surgeons regarding fractures of the acetabulum. This point of view, perhaps, has accounted for the recent increase in enthusiasm for initial open reduction and internal fixation of these fractures. One may ask why such a gloomy outlook developed for these fractures [2,4,9].

A possible reason for the poor results that are reported in the literature may be that patients referred to large clinics and general hospitals with acetabular fractures are likely to fall into one of the three categories:

1. Those whose injuries are the more serious;

2. Those who have not responded well to treatment elsewhere and are therefore referred because they have avascular necrosis of the femoral head or late traumatic changes of the joint;

3. Patients with old fractures and poor results who enter the larger hospital for reconstructive procedures. The poor results are therefore not evaluated in their proper relationship to the good results, and the proportion seems higher.

The purpose of this report, therefore, is to present a more representative account of this injury by reviewing the results of all acetabular fractures that received their initial treatment at one hospital.

PROCEDURE OF STUDY

This study includes consecutive patients admitted to the Massachusetts General Hospital with fractures of the acetabulum. All patients were treated by members of this staff and were seen personally for the follow-up examination by us and members of the Fracture Clinic.

Patients who did not receive their initial treatment at this hospital are not included. Patients who were referred because of developing traumatic arthritis or avascular necrosis of the femoral head were omitted. Dislocations of the hip, unless associated with an acetabular fracture, were also omitted.

Ninety-three acetabular fractures in ninety patients are reported. There were three patients with bilateral fractures of the acetabulum. Seventy-three per cent of the patients were male, and 27 per cent of the patients were female. The youngest was nine, and the oldest was eighty-two years of age. The age incidence by decade is shown in Table I.

Follow-up Study

No patient was evaluated less than one year after injury. The longest follow-up was twenty-seven years. Fifty-one fractures (55 per cent) were followed from one year to five years, and forty-two fractures (45 per cent) were followed from six years to twenty-seven years. The average duration of follow-up study was six years (Table II).

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 1, 1960.

TABLE I

THE INCIDENCE OF ACETABULAR FRACTURES IN RELATION TO AGE

Age of Patients (*Years*)	Types of Fracture				
	Linear Undisplaced	Posterior	Inner Wall	Superior and Bursting	Total
1 to 10	1				1
11 to 20	4	3	1	5	13
21 to 30	4	7	1	6	18
31 to 40	4	2	4	2	12
41 to 50	1	1	7	4	12
51 to 60		2	4	4	10
61 to 70	3	2	3	3	11
71 to 80	5		8	2	15
Over 80			1		1
Totals	21	17	29	26	93

TABLE II

TIME INTERVAL BETWEEN INJURY AND FOLLOW-UP EXAMINATION *

Time Interval (*Years*)	Types of Fracture				
	Linear Undisplaced	Posterior	Inner-wall	Superior and Bursting	Total
1	3	4	5	4	16
2	1	2	1	6	10
3	4	2	4		10
4	2	1	2	2	7
5	1	1	3	3	8
6	2		1	3	6
7	3		2	2	7
8	1	2	1	1	5
9	1		1		2
10	1		3	1	5
11		1		1	2
12	1			2	3
13					
14		1		1	2
15		2	1		3
16	1				1
17			2		2
20		1		1	2
23			1		1
27			1		1
Totals	21	17	29	26	93

* The average duration of follow-up evaluation was six years; there were ninety patients, three of whom had bilateral fractures.

Method of Follow-up Evaluation

All patients received both clinical and anatomical ratings that were based on an evaluation of the hip function and the roentgenographic findings. Those patients who had a Vitallium cup arthroplasty as part of their initial treatment were evaluated separately from those who did not. Patients who had a cup arthroplasty or hip fusion performed at a later date as a reconstructive procedure were given a final clinical and anatomical rating for their hips prior to this later operation. The system of rating employed is shown in Table III.

Classification of Acetabular Fractures

The type of fracture produced in the acetabulum depends on the direction and intensity of the force applied by the femoral head (Table IV).

TABLE III

CRITERIA FOR GRADING OF RESULTS *

Excellent	Good	Fair	Poor
Clinical:			
No symptoms; no medication; full motion; no limp; no support; sustained activities; all sports; returned to original job	Minor complaints; no medication; 25 per cent limitation of motion; no limp; no support; sustained activities; all sports; returned to original job	Discomfort intermittent; relieved by rest and salicylates; mild sciatic-nerve symptoms; 50 per cent limitation of motion; intermittent limp; occasional support; adjustment of work in original job	Constant pain; frequent medication; disturbing sciatic-nerve symptoms; 75 per cent limitation of motion; constant limp; activities limited; full-time support; not able to work
Anatomical:			
Normal joint space; no head changes	Fractured fragments have healed with a smooth congruous articulating surface; no head changes; less-than-normal anatomy; adequate joint space; mild myositis ossificans	Mild-to-moderate narrowing of the joint space; early arthritic changes and osteophyte formation; mild changes in contour of the femoral head; moderate myositis ossificans	Very narrow joint space; advanced arthritic changes; sclerosis and spur formation; definite avascular necrosis of the femoral head with cystic changes; advanced myositis ossificans

* The initial cup arthroplasties were also graded according to the above criteria, with the exception that head changes could not be graded anatomically.

TABLE IV

CLASSIFICATION OF ACETABULAR FRACTURES

I. Linear Undisplaced Acetabular Fractures
   A. Single line
   B. Stellate

II. Posterior Acetabular Fracture
   A. Small rim fractures
   B. Large displaced posterior sector

III. Inner-Wall Fracture
   Intrapelvic displacement of inner acetabular wall; the superior acetabular dome remains intact
   A. Minor intrapelvic displacement
   B. Moderate intrapelvic displacement
   C. Severe intrapelvic displacement

IV. Superior and Bursting Fracture
   These may involve multiple sections of the acetabulum in varying combinations
   A. Superior-dome fractures in acceptable position and in good relation to the femoral head
   B. Displaced fractures of the superior dome
   C. Complete disruption of entire acetabular socket

Linear undisplaced fractures: A relatively mild force produces a typical undisplaced acetabular fracture, which is usually a single transverse or oblique line but may consist of multiple lines.

Fractures of the posterior portion of the acetabulum: A force applied along the long axis of the femur when the hip is flexed, as in the typical dashboard injury, is transmitted to the posterior part of the acetabulum. Small fractures of the posterior rim may result, or large sections may be displaced, which may or may not leave the hip stable after reduction of the dislocation.

Inner-wall fractures: A force applied to the lateral aspect of the greater trochanter produces this fracture. The inner wall of the acetabulum and a portion of the superior pubic ramus are displaced inward, leaving the superior dome of the acetabulum intact. This fracture is associated with varying degrees of intrapelvic protrusion of the femoral head. When the femoral head is reduced beneath the superior dome by closed manipulation, the hip, as a rule, is stable.

Fractures of the superior portion of the acetabulum and bursting fractures: Fractures of the superior portion of the acetabulum occasionally occur alone, but,

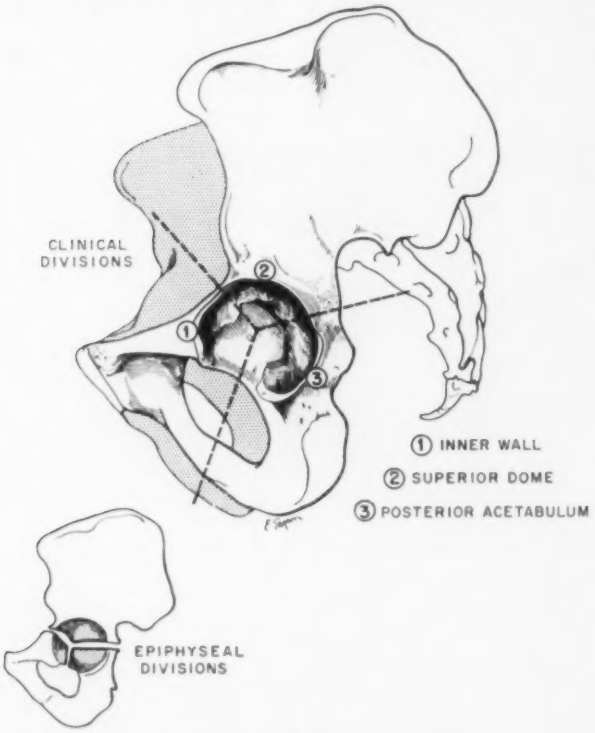

FIG. 1

The acetabulum may be divided into thirds for clinical classification. These divisions conform closely to the original epiphyseal primary centers. *1* = pubis, *2* = ilium, *3* = ischium.

usually, they are combined with fractures characterized by more or less bursting of the socket. These two types of fracture are grouped together because they pose similar problems in management and have a similar prognosis. The displaced fractures limited to the superior portion of the acetabulum result from a direct upward thrust of the femoral head, whereas the bursting fractures follow a violent medial and upward thrust. When the force is great, all parts of the acetabulum may be completely disrupted. Thus, in this category, we have a variety of explosive fractures that are different from the isolated fractures of the posterior acetabulum or of the inner wall of the acetabulum.

We have intentionally omitted from this classification the term *central* for we believe that, as it is being used currently, the term is too inclusive and its implications may be misleading in planning treatment and estimating prognosis. At the inception of this study we, too, were using this term, but it gradually

became evident that a subdivision was necessary into the two categories last described: inner-wall fractures on the one hand, and superior and bursting fractures on the other. Many of the roentgenograms reproduced in the literature today as examples of central fractures of the acetabulum show fractures of the inner wall and fractures of the superior and bursting type under the single heading. As the inner-wall fracture differs specifically in appearance, prognosis, and treatment from the superior and bursting types, we have come to the conclusion that, for clarity, they must be separated.

Anatomy of the Acetabulum

For clinical purposes the acetabulum may be divided into thirds (Fig. 1). These clinical divisions actually conform closely to the original divisions of the acetabulum outlined by the triradiate cartilage.

FIG. 2-A

FIG. 2-B

Figs. 2-A and 2-B: Linear undisplaced fracture.

Fig. 2-A: H. B., a woman twenty-two years old, in 1954 sustained a direct blow on the lateral aspect of the right hip while skiing.

Fig. 2-B: Follow-up roentgenogram in 1956. The patient had full range of painless motion and no restriction of physical activities. The clinical and anatomical ratings were *excellent*.

The superior third of the acetabulum is the most important part of the acetabulum, as it is the chief weight-bearing area of the joint. The bone in this section is thick and strong. An appreciable force is required to fracture it.

The posterior third of the joint has clinical significance because it maintains the stability of the joint. The bone in this area, as in the superior vault, is thick, and requires an equally forceful blow to fracture it. The proximity of the sciatic nerve to the posterior aspect of the hip joint makes the nerve vulnerable to injury from displaced fractures or during surgical procedures.

The inner wall and inferior portion of the acetabulum is thin in comparison with that in the superior and posterior portions. Much less force is required to produce a fracture here, and fractures in this region heal rapidly, the new bone apparently molding evenly to the femoral head. It is significant to note that disruption of this part of the acetabulum has little influence on subsequent function of the hip.

LINEAR UNDISPLACED FRACTURE

There were twenty-one fractures of this type in the series. No patient had bilateral fracture. Sixty per cent of these fractures showed only a single fracture line. Forty per cent showed multiple fracture lines. Twenty per cent were caused by a direct blow to the trochanter, and 40 per cent by automobile accidents.

FIG. 3-A

FIG. 3-B

Figs. 3-A through 3-C: Posterior acetabular fracture. F. B., a man fifty-six years old, sustained a dashboard injury to his knee while driving his automobile.

Fig. 3-A: Roentgenogram made on February 23, 1959, demonstrating the posterior fracture-dislocation of the right hip. Immediate closed reduction was performed, followed by skeletal traction using a Kirschner wire in the tibial tubercle.

Fig. 3-B: Open reduction with internal fixation with two screws was carried out on March 3, 1959, due to marked instability of the hip.

FIG. 3-C

Roentgenogram made at follow-up one year later in 1960. There was full range of painless motion the patient had no restriction of activities. The clinical and anatomical ratings were *excellent*.

The fracture line was usually demonstrated clearly on anteroposterior roentgenograms of the hip (Figs. 2-A and 2-B). Oblique views, in some instances, demonstrated the size and depth of the fracture line more satisfactorily.

All undisplaced linear fractures were treated conservatively. Pain usually disappeared within three to six weeks. One patient in every five was out of bed at the end of one week, and 90 per cent of the patients were out of bed by the eighth week. Fifty per cent of the patients used crutches for eight weeks. If crutches or supports were required after the tenth week this was usually because of associated injuries.

There was no instance of late traumatic arthritis, avascular necrosis of the

FIG. 4-A

FIG. 4-B

Figs. 4-A and 4-B: Unrecognized posterior acetabular fracture. M. G., a woman sixty-three years old, sustained a dashboard injury. Posterior dislocation of the left hip was reduced immediately after admission to the hospital, and the extremity was placed in traction.

Fig. 4-A: Anteroposterior roentgenogram of the pelvis made after reduction of the left hip. Two weeks later the patient complained of burning pain and tingling down the posterior and lateral aspect of her left extremity when she sat up in bed.

Fig. 4-B: The oblique roentgenogram of the left acetabulum demonstrated a large, markedly displaced fragment of the posterior acetabulum that was not obvious on the anteroposterior view of the pelvis.

femoral head, or myositis ossificans in this group of fractures. There was clinical evidence of fat embolism in one patient, and thrombo-embolic disease in three patients (a clot was removed from the femoral vein on the side of the fracture in one patient). Seventy per cent of these patients had associated injuries. Two patients had clinical hematuria, and one had a ruptured urethra.

The results (Table V) were evaluated in eleven (52 per cent) of these fractures one to five years after injury, and in the remaining ten fractures (48 per cent) six to thirteen years after injury. The clinical result was *excellent* in nineteen and *good* in two; the anatomical result was *excellent* in twenty and *good* in one. There was thus a close correlation between the clinical and anatomical result.

POSTERIOR ACETABULAR FRACTURE

This fracture occurred in seventeen instances, or 18 per cent of the total number of fractures. No patient had bilateral fracture. In twelve there were large displaced posterior fragments, and in five there were smaller fractures of the posterior rim.

The majority of these fractures was caused by severe blows on the anterior aspects of the flexed knee when the hip was in flexion. Seventy-seven per cent of these fractures were incurred when the patients were riding in the front seat of an automobile.

As a rule, this fracture can be identified on routine anteroposterior roentgenograms of the hips (Figs. 3-A through 3-C). However, when the posterior rim has been rotated and displaced posteriorly, the fracture may be completely missed on the routine anteroposterior views of the pelvis (Fig. 4-A). Oblique views are necessary to determine accurately the size and the extent of the displacement of the fragment (Figs. 4-B and 5). In two instances, symptoms of involvement of the sciatic nerve were the first indication of an unrecognized posterior acetabular fracture.

Six of the seventeen posterior acetabular fractures (35 per cent) were associated with evidence of sciatic-nerve injury. There were four incomplete and two

complete peroneal palsies. All the patients with incomplete paralysis of the peroneal nerve recovered, but both patients with complete paralysis had residual evidence of nerve-root injury. One patient who was treated conservatively still had a drop-foot deformity two years after injury. The other patient was treated by open reduction; the sciatic nerve was found pierced by the posterior bone fragment. Six months after operation the drop-foot deformity disappeared, but five years after injury there was still some residual hypesthesia over the dorsum of the foot. Avascular necrosis of the femoral head occurred in four cases, and traumatic arthritis occurred in four cases. Cartilaginous or osseous damage to the femoral head was found at operation or shown by roentgenograms in eight cases. Three patients had associated open fractures of the knee. Myositis ossificans developed in five patients, all of whom had been operated on; this complication

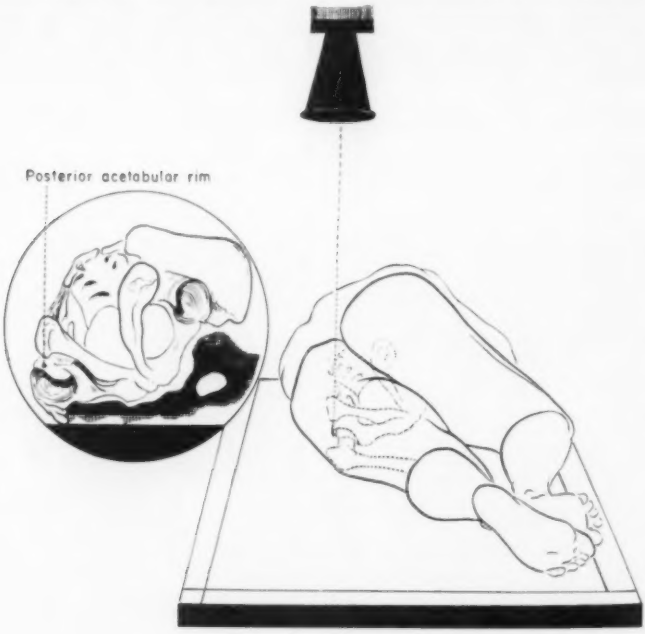

FIG. 5

Roentgenographic technique to demonstrate the presence of displaced posterior acetabular fractures. The patient is placed prone on the table; the uninjured hip is then rotated upward 45 to 60 degrees so that the patient is lying semiprone on the injured side. This maneuver should be supervised by the surgeon. The x-ray tube is centered over the injured hip, and the beam is directed perpendicular to the table.

did not occur in patients treated conservatively. Thrombophlebitis occurred in one patient; a clot was removed from the femoral vein on the side of the fracture.

The results (Table VI) were evaluated in ten (59 per cent) of these fractures from one to five years after injury and in seven (41 per cent) of the remaining fractures of this group six to twenty years after injury. Both the clinical and anatomical results were *excellent* in seven, *good* in four, and *poor* in six, making the results satisfactory in 65 per cent and unsatisfactory in 35 per cent of the cases.

An analysis of the six fractures with *poor* results showed that the important factors contributing to these poor results were instability of the hip resulting from the fracture, delayed reduction of the dislocation, and injury to the femoral head. Three patients were treated by closed means in traction but had resultant in-

stability or posterior subluxation of their hips. All had *poor* results. Delayed open reductions were done in three patients after multiple unsuccessful attempts at closed reduction (Figs. 6-A, 6-B, and 6-C). All three had *poor* results. The time interval between injury and open reduction for these three patients was one, two, and three weeks, respectively. All six patients with *poor* results had femoral-head injuries, and three of these patients had recognizable bone fragments in the joint.

Of the eleven fractures with *excellent* and *good* results, all had early reduction of the dislocation and restoration of a stable hip. The dislocations in all eleven cases were immediately reduced when the patient was admitted to the hospital. Stability of the hip after closed reduction was satisfactory in three patients (Figs. 7-A through 7-C). In the other eight patients, open reduction and internal fixation were necessary to obtain stability (Figs. 3-A through 3-C). The timing of open

TABLE V

RESULTS IN LINEAR UNDISPLACED ACETABULAR FRACTURES

Clinical Result			Anatomical Result		
Excellent	19	100%	Excellent	20	100%
Good	2		Good	1	
Fair	0		Fair	0	
Poor	0		Poor	0	
Total	21		Total	21	

TABLE VI

RESULTS IN POSTERIOR ACETABULAR FRACTURES

Clinical Result			Anatomical Result		
Excellent	7	65%	Excellent	7	65%
Good	4		Good	4	
Fair	0	35%	Fair	0	35%
Poor	6		Poor	6	
Total	17		Total	17	

reduction and fixation of the posterior fragment was of little importance, so long as the femoral head was reduced early.

The time intervals between injury and open reduction and fixation of the displaced posterior fragment were: five days in two patients, eight days in three patients, thirteen days in one patient, sixteen days in one patient, and nineteen days in one patient.

It was significant that in all the hips with *good* and *excellent* results, there was no evidence of appreciable injury to the femoral head. At operation, all bone chips found in the joint were removed.

From these findings it may be concluded that, with posterior acetabular fractures:

Immediate reduction of the dislocated hip is indicated, either by closed or open methods;

Open reduction is indicated when there are large displaced posterior acetabular fragments that must be reduced and fixed to restore stability of the joint;

When sciatic-nerve pressure or injury is associated with displacement of bone fragments, exploration of the nerve should not be delayed;

Closed reduction is satisfactory when the posterior acetabular fragments are small and their reduction and fixation are not necessary to restore stability of the joint;

FIG. 6-A

Figs. 6-A through 6-C: J. C., a man twenty years old, was injured in an automobile accident on February 18, 1951.

Fig. 6-A: In addition to the dislocation there were a posterior and inner-wall fracture of the acetabulum and a fracture of the femoral head. Several unsuccessful attempts at closed reduction were made. When the patient's general condition improved, open reduction of the hip was carried out one week after admission to the hospital.

FIG. 6-B

FIG. 6-C

Fig. 6-B: Roentgenogram made at follow-up two years later, showing avascular necrosis of the left femoral head.

Fig. 6-C: Roentgenogram showing the left hip seven years after injury and five years after surgical fusion.

Early oblique views of the acetabulum are frequently necessary to determine the size and degree of displacement of the bone fragments.

FRACTURE OF THE INNER WALL OF THE ACETABULUM

This was the commonest type of acetabular fracture, occurring in twenty-nine instances, or 31 per cent of the whole series; one patient had bilateral fracture. Seventy-six per cent of the inner-wall fractures occurred in patients over forty years of age. Associated with these fractures there were minor intrapelvic protrusion of the femoral head in six, moderate intrapelvic protrusion in nineteen, and severe intrapelvic protrusion in four patients.

Because the inner wall of the acetabulum is thin, a relatively small force is required to produce this fracture, and when the inner wall of the acetabulum is

FIG. 7-A

FIG. 7-B

Figs. 7-A through 7-C: T. B., a man twenty-three years old, was injured in an automobile accident, sustaining a fracture with posterior dislocation of the left hip on December 8, 1955.

Fig. 7-A: Roentgenogram showing posterior dislocation of the left hip without evidence of fracture. The hip was reduced by closed manipulation.

Fig. 7-B: Oblique view of the pelvis after reduction. This roentgenogram was made with the patient lying semiprone with the injured side down and the normal side rotated upward 75 degrees. No fragments were visible in the joint. The hip was stable. There were no sciatic-nerve symptoms. The patient was treated by traction and suspension for five weeks. Active exercises were then started, and the patient began walking with crutches ten weeks after injury. Full weight-bearing was begun two months later.

FIG. 7-C

Follow-up roentgenogram in October 1959, four years after injury, at which time the patient had full range of painless motion. His result was graded *excellent* clinically and *good* anatomically.

driven in, the superior dome may be left intact. Seventeen (59 per cent) of these fractures were caused by a direct blow to the greater trochanter.

All these fractures were visible on routine anteroposterior roentgenograms of the pelvis. However, one may be easily deceived by these routine roentgenograms when attempting to estimate the exact depth and location of the displaced medial or central fragment and the depth of protrusion of the femoral head.

Associated fractures of the pubic rami were common in fractures of the inner wall of the acetabulum, occurring in 43 per cent of the patients. Sciatic-nerve palsies occurred in four patients (14 per cent). There was one unusual occurrence, a fracture of the neck of the femur of the same side as the acetabular fracture. Thrombophlebitis occurred in only one patient in this group. One patient had a ruptured urethra. There were no fractures of the femoral head. Myositis ossificans

TABLE VII

RESULTS IN INNER-WALL ACETABULAR FRACTURES *

Clinical Evaluation			Anatomical Evaluation		
Excellent	18	90%	Excellent	11	83%
Good	8		Good	13	
Fair	3	10%	Fair	5	17%
Poor	0		Poor	0	
Total	29		Total	29	

* One hip included above was treated by an initial Vitallium cup arthroplasty, which was graded *good* clinically and *good* anatomically.

TABLE VIII

RESULTS IN SUPERIOR AND BURSTING ACETABULAR FRACTURES *

Clinical Evaluation			Anatomical Evaluation		
Excellent	9	58%	Excellent	5	54%
Good	6		Good	9	
Fair	5	42%	Fair	4	46%
Poor	6		Poor	8	
Total	26		Total	26	

* Two hips included above were treated by initial Vitallium cup arthroplasty. One was graded clinically and anatomically *good*. The other was graded *excellent* clinically and *good* anatomically.

FIG. 8-A

FIG. 8-B

Figs. 8-A and 8-B: Unreduced inner-wall fracture. J. E., a man sixty-one years old, fell on his left greater trochanter on February 14, 1952.

Fig. 8-A: Roentgenogram illustrating a displaced fracture of the inner wall with acceptable position of the head under the intact superior acetabulum. No attempt was made to reduce the displaced inner wall. Treatment consisted in traction and suspension of the limb for one month, during which exercises were carried out. The patient then began walking with crutches for one month and returned to work three months after injury.

Fig. 8-B: Follow-up roentgenogram, seven years after injury. The patient had complete range of painless hip motion and no restriction of activities. The result was graded *excellent* both clinically and anatomically.

developed in only one patient. Perhaps this was due to the fact that open surgery was employed in only two of these fractures of the inner wall.

The results (Table VII) were evaluated in fifteen (52 per cent) of these fractures from one to five years after injury, and in the remaining fourteen (48 per cent) from six to twenty-seven years after injury. The clinical results were *excellent* in eighteen, *good* in eight, and *fair* in three, giving *good* and *excellent* clinical results in 90 per cent and *fair* results in 10 per cent. The anatomical results were *excellent* in eleven, *good* in thirteen, and *fair* in five, giving *good* or *excellent* results in 83 per cent and *fair* results in 17 per cent. One hip was treated by the insertion of a Vitallium mold initially. The clinical result in this hip was rated as *good*. The high incidence of *excellent* and *good* results in this group is noteworthy.

FIG. 9-A

Figs. 9-A and 9-B: Inner-wall fracture with seventeen-year follow-up. P. H., a man twenty-four years old, was injured in a tractor accident on July 3, 1942.

Fig. 9-A: Sketch made by C. R. R. in 1946 from the original roentgenogram, which was subsequently destroyed.

FIG. 9-B

Roentgenogram of the hips, seventeen years after injury, showing a congruous articular surface, no narrowing of the joint space, and no changes in the femoral head. The patient was treated originally by bedrest for two months, without traction but with early active motion of the hips; the use of crutches for three months; and then no crutches. The result was graded *excellent* both clinically and anatomically.

In this study of fractures of the inner wall of the acetabulum, two significant observations are apparent:

Twenty-seven (93 per cent) of the twenty-nine fractures in this group were treated by closed conservative methods. In only two were initial open surgical procedures done. In one, the surgeon, after opening the hip, decided that the position of the fragments was better than he had anticipated and closed it without using any type of fixation. In the other, an initial cup arthroplasty was performed

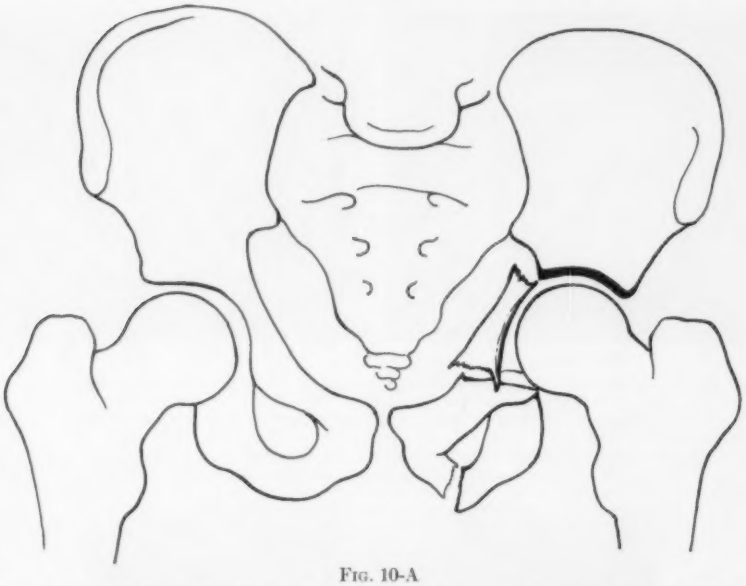

FIG. 10-A

Figs. 10-A and 10-B: Inner-wall fracture with twenty-three-year follow-up. A. A., a man twenty-two years old, was injured on May 13, 1936, when he fell on his left hip.

Fig. 10-A: Sketch made by C. R. R. in 1946 from the original roentgenogram, which was destroyed.

FIG. 10-B

Roentgenogram of the hips made twenty-three years after injury, showing a good joint space smooth joint line, and no changes in the femoral head. The patient had been treated initially by manipulation and closed reduction, which was followed by two weeks in traction and ten days in bed without traction. He used crutches for two months and a cane for several months. At the end of one year, the result was graded *excellent;* at the end of twenty-three years, the result was graded *excellent* clinically and *good* anatomically.

because the surgeon anticipated future trouble. On the basis of the findings in this study we believe that there is little indication for open reduction and internal fixation in this type of fracture.

It is not necessary to reduce the displaced inner wall of the acetabulum, since in all patients the femoral head remained stable under the intact superior dome after the dislocation was reduced. The inwardly displaced fragment was reduced

FIG. 11-A

FIG. 11-B

Figs. 11-A through 11-C: Reduced inner-wall fracture. R. L., a woman forty-three years old, was injured in an automobile accident in July 1950.

Fig. 11-A: Roentgenogram showing severe inner-wall fracture and intrapelvic dislocation of the femoral head.

Fig. 11-B: Roentgenogram showing successful reduction after immediate closed manipulation. Traction and suspension were used for six weeks, and then the patient used crutches for four months.

FIG. 11-C

Roentgenogram made at follow-up nine years after injury. There was complete range of painless motion of the hip. The result was rated *excellent* clinically and *good* anatomically.

in eight patients, coincident with manipulation, and was not reduced in the other twenty-one patients.

Of the twenty-one fractures in which the inner wall was not reduced, the results were *excellent* in fourteen and *good* in four. The three remaining hips were not manipulated because of the patients' general condition. These three femoral heads remained displaced intrapelvically; the results in these cases were graded *fair*. Figures 8-A through 10-B are roentgenograms of unreduced inner-wall fractures in which the clinical result was graded *excellent*.

In the eight fractures in which the inner-wall fragment was reduced by closed

FIG. 12-A

FIG. 12-B

Figs. 12-A through 12-C: Reduced inner-wall fracture. B. T., a woman seventeen years old, was injured in an automobile accident on November 11, 1956.

Fig. 12-A: Inner-wall fracture of the left hip. Note the intact superior acetabular dome and lack of damage to the head of the femur. On admission to the hospital, the patient was immediately manipulated, under anesthesia, by putting a bolster between the thighs and adducting the lower extremities, thus pulling the femoral head out of the acetabulum.

Fig. 12-B: Roentgenogram showing the reduction after manipulation. The patient was treated for six weeks with twenty-five pounds of skeletal traction using a Kirschner wire through the distal part of the femur. Early active exercises and motion of the hip were carried out. The patient was walking with crutches three months after injury and continued to use crutches for two more months.

FIG. 12-C

Three and a half years after injury. There were no head changes; the joint was smooth. The patient had a full range of painless motion and no restriction of activities. Her result was graded *excellent* both clinically and anatomically.

manipulation, the results were *excellent* in five and *good* in three. Typical examples of these inner-wall fractures are shown in Figures 11-A through 12-B.

The time interval between injury and reduction of the intrapelvic protrusion of the femoral head seemed to bear little relation to the outcome in this group, in contrast to the posterior dislocations, in which this interval appeared to be much more significant. The majority of these inner-wall fractures were reduced within twelve hours. However, those that were not reduced for from one to two weeks after injury also had *good* to *excellent* results.

THE SUPERIOR AND BURSTING ACETABULAR FRACTURE

There were twenty-six fractures in this category, or 28 per cent of the whole series. One patient sustained bilateral bursting fracture (Figs. 13-A and 13-B). Seven were superior-dome fractures in acceptable position with a good relation

FIG. 13-A

FIG. 13-B

Figs. 13-A and 13-B: Superior-dome and bursting fracture in acceptable position. Although all elements of the acetabulum are involved to some extent, the superior dome is the most severely damaged.

Fig. 13-A: C. B., a man fifty-nine years old, sustained bilateral fracture of the hip on September 25, 1955. The right hip is shown in an early anteroposterior roentgenogram. Treatment consisted in Russell's traction for three weeks, and then the patient used two canes for six weeks.

Fig. 13-B: Follow-up roentgenogram five years after injury. The result was graded *excellent* clinically and *good* anatomically.

FIG. 14-A

FIG. 14-B

Figs. 14-A and 14-B: Superior-dome and bursting fracture involving the superior dome primarily.

Fig. 14-A: C. C., a woman sixty-one years old, fell on her hip in March 1948. Anteroposterior roentgenogram of the left hip, demonstrating marked comminution of the superior dome, with minimally displaced fractures of both the inner wall and posterior margin of the acetabulum. Note also the depressed fracture of the superior lateral aspect of the articular surface of the femoral head. These changes were shown more clearly on stereoscopic views. Treatment consisted in open reduction and internal fixation six days after entry; this was followed by traction for one month, bed exercises for two weeks, and the use of crutches for six months.

Fig. 14-B: Roentgenogram made eleven and a half years after injury. The indentation in the femoral head is still present. The patient's hip motion was painless but slightly limited; she was active and had no limp. The result was rated *good* clinically and *fair* anatomically.

between the femoral head and dome of the acetabulum; thirteen were displaced fractures of the superior dome; and six were complete disruptions of the entire acetabular socket.

These fractures resulted from the severest trauma to the acetabulum. All were caused by major violence, such as severe automobile accidents, falls from windows, or crushing injuries.

Although routine anteroposterior roentgenograms of the pelvis show clearly

FIG. 15-A

FIG. 15-B

Figs. 15-A through 15-C: Superior-dome and bursting fracture with good prognosis. Although there are fractures involving all sections of the acetabulum, the central portion of the superior dome is intact and in good relationship to the femoral head.

Fig. 15-A: J. McG., a woman twenty-three years old, was in an automobile accident in June 1950. The roentgenogram was made soon after injury. Treatment consisted in skeletal traction using a Kirschner wire through the femoral condyle for three weeks, followed by partial weight-bearing on crutches for four months.

Fig. 15-B: At the follow-up at one year there was complete, painless hip motion.

FIG. 15-C

At the follow-up at ten years there was still complete function with no symptoms. The result was graded *excellent* clinically and *good* anatomically.

the severe disruption of the acetabulum, it is difficult, and at times impossible, in these views to determine accurately the depth of displacement and the exact location of the fractured fragments. A large fragment that may appear to be displaced medially on these roentgenograms may be found actually to be displaced far posteriorly. Special views, such as oblique and stereoscopic views, should be obtained and considered before an open reduction is undertaken. In many instances, among those patients studied who sustained one of these two types of fracture, much more damage to the acetabulum was found at operation than had been predicted beforehand (Figs. 14-A, 14-B, and 16-A through 16-C).

Six of the twenty-six patients had sciatic-nerve injuries. Two patients had

FIG. 16-A

FIG. 16-B

Figs. 16-A through 16-C: Unreduced superior acetabular fracture with poor result. N. B., a man sixty-eight years old, received a direct blow to his hip in a fall in March 1957.

Fig. 16-A: The anteroposterior roentgenogram shows the superior acetabular fracture but does not give a clear indication of the amount of displacement.

Fig. 16-B: The oblique view demonstrates more clearly the extent of the fracture and the degree of displacement; this emphasizes the advantages of this projection. An open reduction was perhaps indicated in this instance, but treatment consisted in the use of Russell's traction for five days, and then the patient was allowed to walk with crutches for three months and with a cane for three additional months. A longer period in bed with active exercises to allow the fractures to heal and the damaged acetabulum to mold to the femoral head might have produced a better result.

FIG. 16-C

Eighteen months after injury there are extensive degenerative arthritic changes with avascular necrosis of the femoral head. The result was graded *fair* clinically and *poor* anatomically.

serious hematomata within the pelvis. There were four patients with myositis ossificans; in two of these patients this complication followed operation. Thrombophlebitis developed in two patients. Damage to the femoral head occurred in five patients.

The results (Table VIII) were evaluated in fifteen (58 per cent) of these frac-

FIG. 17-A

FIG. 17-B

Figs. 17-A and 17-B: Unreduced bursting fracture with *poor* result. B. F., a man forty-five years old, was crushed between two railroad cars on November 12, 1952. Treatment of the hip consisted in traction in suspension for two weeks and the use of a walker for two months. Prolonged use of the walker was necessitated by an associated fracture of the opposite femoral shaft that had been fixed with a Küntscher rod.

Fig. 17-A: The anteroposterior roentgenogram made five months after injury demonstrates a markedly displaced comminuted fracture of the superior acetabulum.

Fig. 17-B: The anteroposterior roentgenogram made one year after injury shows that advanced avascular necrosis of the femoral head and traumatic arthritis had already developed. This hip never regained normal motion, and the patient was never free from pain from the outset. Five years after injury a Vitallium mold arthroplasty was performed because of increasing pain and limitation of motion.

tures from one to five years after injury, and, in the remaining eleven (42 per cent), from six to twelve years after injury. The clinical results were *excellent* in nine, *good* in six, *fair* in five, and *poor* in six, giving *good* or *excellent* results in 58 per cent and *fair* or *poor* in 42 per cent. The anatomical results were *excellent* in five, *good* in nine, *fair* in four, and *poor* in eight, giving *good* and *excellent* results in 54 per cent and *fair* and *poor* results in 46 per cent. In two instances the initial treatment consisted in the insertion of a Vitallium mold. The clinical results in these two cases were *excellent* in one and *good* in the other.

The over-all results in this group were the poorest in the series. The clinical results were definitely better than the anatomical results. Several investigators [2,5] pointed out that the patient with this type of fracture may have a better hip clinically than the roentgenographic or anatomical rating would indicate.

In this group of fractures the most significant prognostic indicator was found to be the condition of the superior weight-bearing dome. Given a smooth, congruous superior weight-bearing dome in good relation to an intact femoral head, a satisfactory result can be anticipated. Lacking any of these, the result may be unsatisfactory. The validity of this statement is indicated by the following findings:

In the eight patients with superior-dome fractures in acceptable position with a good relationship between the dome and the femoral head, the clinical rating at follow-up was *excellent* and *good* in six and *fair* in two. The anatomical rating was *excellent* and *good* in six, and *fair* in two. All patients in this group were treated by closed methods, followed by traction and suspension (Figs. 13-A, 13-B, and 15-A through 15-C).

Of the thirteen displaced fractures of the superior dome, seven were openly

FIG. 18-A

Figs. 18-A through 18-D: Unstable bursting fracture with poor result following closed treatment. B. R., a man nineteen years old, was run over by a tractor on November 26, 1954.

Fig. 18-A: Anteroposterior roentgenogram made on admission, showing a severe unstable bursting fracture of the acetabulum, posterior superior dislocation of the femoral head, and separation of the symphysis pubis.

FIG. 18-B

Cystometrogram showing displacement of the bladder by a large intrapelvic hematoma.

reduced with internal fixation. Of these, six results were *excellent* and *good* clinically, and one was *poor*. The anatomical rating was *excellent* and *good* in five, *fair* in one (Figs. 14-A and 14-B), and *poor* in one. Six fractures remained unreduced; all were treated by closed methods using traction and suspension. The clinical results in these were *poor* in four and *fair* in two. The anatomical rating was *poor* in five and *fair* in one (Figs. 16-A through 17-B). Four patients in this group had late cup arthroplasties because of hip pain.

FIG. 18-C

Anteroposterior roentgenogram after manipulative reduction. Traction failed to maintain this position. Open reduction was not attempted because of the multiple injuries and major complications. The limb was maintained in traction for two months; the patient then used crutches for three months and a cane for eighteen months.

FIG. 18-D

Anteroposterior roentgenogram five years after injury, showing intrapelvic protrusion of the femoral head and extensive traumatic arthritis. Although motion of the hip when the patient was last examined was limited and the patient was having moderate pain, he was able to work and refused further treatment. The result was graded *fair* clinically and *poor* anatomically.

In the remaining five fractures there was complete disruption of the entire acetabular socket. Two of these fractures were treated by closed methods. In these two fractures the femoral head remained displaced intrapelvically, and in

FIG. 19-A

Figs. 19-A and 19-B: Unstable bursting fracture successfully treated by open reduction and restoration of the superior acetabulum. R. B., a woman thirty-one years old with manic-depressive psychosis, injured her left hip when she jumped from a window in January 1940.

Fig. 19-A: Anteroposterior roentgenogram showing an extremely unstable bursting fracture. An attempt at closed reduction was unsuccessful, and open reduction was performed eight days after injury.

FIG. 19-B

Anteroposterior roentgenogram twenty years after injury, showing the joint space to be well preserved and no traumatic changes. Although the patient remained in an institution and was not active, she walked without a limp and did not complain of pain. The result was rated *good* both clinically and anatomically.

poor relation to a superior acetabulum. One result was *poor* both clinically and anatomically at one year; the other was clinically *fair* but anatomically *poor* at five years (Figs. 18-A through 18-D). Three patients had initial explorations of

FIG. 20-A

Figs. 20-A through 20-C: Completely unstable bursting fracture treated with a Vitallium mold arthroplasty two weeks after injury. J. P., a woman twenty-eight years old, was injured in an automobile accident.

Fig. 20-A: Anteroposterior roentgenogram of the pelvis with the bladder filled with contrast medium, made shortly after injury. All portions of the acetabulum are shattered, making the hip completely unstable. Note the displacement of the bladder by the intrapelvic hematoma. After traction and suspension for two weeks, the hip joint was explored because of constant pain. At operation it was impossible to reduce and fix the displaced fragments so as to reconstruct a satisfactory articular surface. Accordingly, a Vitallium mold was inserted on October 23, 1958. A surprising degree of stability was achieved immediately.

FIG. 20-B

FIG. 20-C

Fig. 20-B: Anteroposterior roentgenogram showing myositis ossificans approximately fifteen months after operation.

Fig. 20-C: One month after revision. The patient was seen eight months after revision. She denied pain, walked without a cane or crutches, and the result was graded *good*.

their hips. In one of these (Figs. 19-A and 19-B) the superior dome could be reconstructed. This patient was rated *good* clinically and anatomically twenty years after injury. At operation the other two patients were found to have severe bursting acetabular fractures, and satisfactory reduction was not possible; consequently, Vitallium cups were inserted, which gave good stability and a smooth surface (Figs. 20-A through 20-C).

Thus, for the sixteen fractures of this group with the superior acetabular dome reduced either by open or closed methods of treatment, the results were graded clinically *excellent* to *good* in thirteen, *fair* in one, and *poor* in one. Of the ten fractures in which the superior acetabular dome was not reduced, the clinical and anatomical results were graded *fair* to *poor* in eight. Two were treated by initial cup arthroplasties, and their final clinical rating was *excellent* for one and *good* for the other. Both were *good* anatomically. When patients had a cup arthroplasty in relation to their initial treatment, the arthroplasty was given a rating. When patients had an arthroplasty performed for late traumatic changes, a clinical and anatomical rating was given the hip prior to the arthroplasty; this was considered the final rating.

Injury to the femoral head was present in four patients. In these, the results were *poor* in three and *good* in one.

There were other factors of less significance in the final outcome. The patients in the *good* and *excellent* group were in bed for an average of two weeks longer than those in the *poor* group. Also, they were on crutches for an average of six weeks longer.

The results in these superior and bursting fractures indicate that initial open reduction should be reserved for those fractures in which the superior acetabular dome is appreciably displaced and has not been sufficiently improved by closed treatment. Even then, open reduction should be attempted only if the fragments are sufficiently large to be manipulated and fixed as necessary to restore a congruous dome over the femoral head. In those instances where there is extreme instability of the hip and constant pain, an initial cup arthroplasty may provide both stability and relief of pain; otherwise, conservative closed methods should be used.

At a later date, reconstructive procedures can be performed on those patients whose hips become disabled owing to pain.

IMPORTANCE OF ONE-YEAR FOLLOW-UP

A careful follow-up examination one year after injury is important for the surgeon in estimating the prognosis of the hip.

If, at the follow-up examination at one year, the patient's hip is graded *excellent* or *good* clinically and anatomically, the long-range prognosis for a good hip is also *excellent*. Fifty-four results were graded *excellent* at the one-year follow-up; in only three hips was the rating changed to a lower rating — one to *good*, one to *fair*, and one to *poor*. Thus, 94 per cent of the patients with hips graded *excellent* at one year remained *excellent* during the period covered by this study.

Ninety-one per cent of the twenty-four patients in whose hips traumatic arthritis or avascular necrosis developed showed both clinical and roentgenographic evidence of these changes at one year. One patient whose hip was normal at one year first showed evidence of avascular necrosis one and a half years after injury.

Another patient did not show definite changes in the hip until eight years had elapsed.

ASSOCIATED OPERATIVE PROCEDURES

Cup Arthroplasties

Three cup arthroplasties were performed for acetabular fractures on the twelfth, thirteenth, and thirtieth days after injury. Two of these procedures were for bursting fractures, and one was for an inner-wall fracture. In the patient operated on thirteen days after injury, myositis ossificans developed that necessitated a revision one year later; her hip was rated *excellent* two years after injury. In the other two patients with initial cup arthroplasties, myositis ossificans did not develop. These patients received ratings of *good* at follow-up examination nine and six years later, respectively.

Five reconstructive cup arthroplasties were performed for late hip changes; one procedure was carried out at six months, one at one year, two at two years, and one at five years after injury. All procedures were for *poor* results after superior-dome fractures, with the exception of one, which was for an unreduced posterior fracture.

In two patients spontaneous fusions of the hip developed. One patient had a posterior acetabular fracture for which multiple unsuccessful attempts at closed reduction were followed by a late open reduction. The second patient had a severe bursting fracture.

Two patients had surgical fusion performed because of poor clinical results seven months and two years, respectively, after injury. One had a posterior fracture, and the other had an unreduced superior bursting fracture.

OVER-ALL COMPLICATIONS

Traumatic Arthritis and Avascular Necrosis of the Femoral Head

This complication occurred in twenty-four of the ninety-three acetabular fractures, a incidence of 26 per cent. There were twelve cases of predominantly traumatic arthritis, and twelve cases of avascular necrosis. Bursting fractures produced the highest incidence of both these changes. Eight of the twelve hips with traumatic changes had had bursting fractures, and six of the twelve hips with avascular necrosis had had bursting fractures. In only four of the posterior fractures did avascular necrosis develop. These changes were mild in eight hips, moderate in three, and severe in thirteen.

Avascular necrosis and early traumatic arthritis of the hip were diagnosed by roentgenograms in twenty-two of the hips one year after injury. In the remaining two hips, changes appeared between the twelfth and eighteenth month after injury in one, and, in the other, joint changes were not apparent by roentgenogram until eight years after injury.

Thus in our series, 91 per cent of the hips in which traumatic arthritis or avascular necrosis of the femoral head developed demonstrated these changes by roentgenograms at one year. It is significant that these hips were never out of trouble from the outset. Either pain persisted, or the motions of these hips were limited, or the patients concerned were unable to give up their crutches or cane.

Myositis Ossificans

Myositis ossificans occurred in fourteen hips, or 15 per cent of the series. This complication developed in three (5 per cent) of sixty-one fractures treated by closed methods, whereas among the thirty-two fractures treated by open surgery from one to nineteen days after injury, this complication developed in eleven, or 34 per cent. The low incidence of myositis ossificans after closed methods of treatment was also pointed out by Stewart and Milford.

The anterior approach was used in seventeen patients; in eight (44 per cent)

myositis ossificans developed. The posterior approach was used in fifteen patients, and in three (20 per cent) this complication developed. Of the three initial cup arthroplasties, myositis ossificans developed in one. The question is frequently asked, "Is there any relation between the development of myositis ossificans and the time intervals between injury and operation on the hip?" Our series is too small to provide an answer to this question, but it is our impression that the first ten to twelve days after injury are a poor time to perform open surgery.

Femoral-Head Damage

Damage to the femoral head was known to have occurred in thirteen hips, eight of which had posterior acetabular fractures. The results in all but three of these were rated *poor*.

Associated Fractures of the Femoral Neck and Shaft

One inner-wall acetabular fracture occurred in association with a femoral-neck fracture in the same hip. Both fractures healed. There was also one instance of a femoral-shaft fracture and a linear undisplaced acetabular fracture in the same extremity, both of which healed uneventfully.

Sciatic-Nerve Palsy

There were sixteen instances of sciatic palsy (17 per cent). Ten of these palsies were temporary, and six resulted in residual signs and symptoms that were still present when the patients were last examined. No paralysis of the sciatic nerve occurred with an undisplaced fracture, but there were six instances with the posterior acetabular fractures, three with inner-wall fractures, and seven with bursting fractures.

Paget's Disease

Paget's disease was present in two hips, in each instance involving the acetabulum only: one with a linear undisplaced fracture, and the other with an inner-wall fracture. This disease did not seem to affect the healing of the acetabular fracture or to retard the return of the joint function. One result was graded *excellent* six years after injury.

Hemorrhage or Vascular Disease

When cystograms were performed on patients with bursting fractures of the acetabulum, there was usually evidence of a filling defect within the pelvis. These defects were presumed to be caused by hematomata. In several instances there was evidence by cystogram of a very large accumulation of blood (Figs. 18-B and 20-A). The only serious vascular injury occurred in a nine-year-old boy with a linear undisplaced fracture of the acetabulum. This patient had a laceration of the femoral vein under Poupart's ligament, as well as multiple other injuries that were more serious than his acetabular fracture. Thrombophlebitis occurred in nine instances, and organized clots were removed in two patients. No major arterial injury was encountered in this series.

Ruptures of Urethra or Bladder

A lacerated bladder was found in one patient with an inner-wall acetabular fracture. Two ruptured urethras occurred, one in a patient with a linear undisplaced fracture; the other in a patient with an inner-wall fracture of the acetabulum. Hematuria was present on three occasions without demonstrable genitourinary injury.

Postoperative Infections

In thirty-one open surgical exposures of the hip, two postoperative infections occurred (6 per cent). One was a delayed infection that became evident eight months after injury, and the other appeared within ten days. Both infections responded to treatment, and the final results in these hips were rated *good*.

Fat Emboli

One patient with a linear undisplaced acetabular fracture of the right hip had serious fat emboli. His associated injuries, including an anterior dislocation of the left hip and a fracture of the right femoral shaft, were thought to be the causative factors of the fat emboli.

Other Associated Complications

Fifty-one per cent of the patients had one or more other injuries of minor to major consequence involving the upper or lower extremities, or the head, chest, or abdomen. No patient had a ruptured spleen. Two lumbar vertebrae were fractured; one associated with a linear undisplaced acetabular fracture, and the second with an inner-wall fracture. Open patellar fractures occurred in four instances; three of these patients had posterior acetabular fractures. Pneumothorax occurred in three patients with posterior acetabular fractures.

OVER-ALL PROGNOSIS

The results of our follow-up study are summarized in the various tables. These figures indicate that the prognosis of acetabular fractures is much better than has been generally thought up to now.

Eighty per cent of the acetabular fractures that were examined for follow-up evaluation in this study were rated *excellent* or *good* clinically, and 75 per cent, *excellent* or *good* anatomically. When linear undisplaced fractures of the acetabulum are omitted, and the results of the displaced fractures are considered alone, the results are still favorable; 70 per cent of the results were rated *excellent* or *good* clinically.

The prognosis for linear undisplaced fractures is extremely good as proved by this study. All fractures were treated by closed methods, and there were no serious late changes in the joints.

Sixty-five per cent of the posterior acetabular fractures did well, both clinically and anatomically. Of the 35 per cent that did poorly, residual instability of the hip resulting from the acetabular fracture, delayed reduction of the dislocation, or injury to the femoral head were responsible.

Inner-wall acetabular fractures, including those associated with and without intrapelvic protrusion of the femoral head, have an extremely favorable prognosis. In this study, the clinical results were *excellent* and *good* in 90 per cent of these fractures. These good clinical results are paralleled by the anatomical results, which were *excellent* and *good* in 82 per cent. Ninety-three per cent of these fractures were treated by initial closed manipulation and conservative means. The results were equally as good in the fractures in which the displaced inner wall of the acetabulum was left unreduced as they were in those fractures in which it was reduced. The important factor was the reduction of the head of the femur to its normal position beneath the dome of the acetabulum. Only two patients had initial open surgery in this group. Our experience with these fractures, which have long-term follow-up studies, leads us to state with considerable assurance that open surgery to reduce the displaced central or inner wall of the acetabulum is unnecessary.

The superior and bursting fractures in this series were the result of severe trauma to the hip. The largest percentage of poor results were found in this group (42 per cent). A favorable outcome was found to be dependent on two factors: an intact superior acetabular dome, and a good relation between it and the femoral head. When these two conditions were present or could be obtained by closed or open reduction, these fractures did very well. When these conditions were not present, or could not be obtained, the results were poor. Other important factors that were found to have definite relation to the prognosis were injury to the femoral head and retained loose bodies in the joint. It is reasonable to assume that there is some degree of injury to the femoral head in every acetabular fracture, and that the degree of injury varies in relation to the trauma and type of fracture. Our results indicated that the more serious the femoral-head injury, the poorer the prognosis for the hip.

The time interval before reduction of the dislocation was more important in relation to the prognosis of a posteriorly dislocated hip than it was in relation to the prognosis of a hip dislocated intrapelvically.

The length of time that the patient was maintained on non-weight-bearing and on partial or protected weight-bearing may have had some relation to the outcome. The patients who remained in bed longer and did not give up their crutches too early seemed to have a higher incidence of *excellent* and *good* results.

SUMMARY

An end-result study of ninety-three acetabular fractures in ninety patients followed for from one to twenty-seven years, or for an average of six years, is presented. These fractures were classified as undisplaced, posterior, inner-wall, and superior or bursting fractures. The prognosis would be different in the different types of fracture, but, in general, the prognosis was found to be more favorable than would be anticipated from current reports in the literature. The more favorable outlook for this fracture derived from this study is perhaps due to the fact that the patients studied were all those whose initial treatment was in one hospital. This gave a more representative balance between the good and poor results.

The outcome of the hip appeared to depend primarily on the condition of the dome or weight-bearing portion of the acetabulum, the condition of the femoral head, the adequacy of the reduction of the dislocation, and the stability of the joint after treatment. The clinical and roentgenographic findings in the affected hips one year after injury were found to be a most reliable guide to the ultimate prognosis of the hip, since definite changes were noted at one year in those hips that deteriorated.

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DISCUSSION

DR. MARCUS J. STEWART, MEMPHIS, TENNESSEE: Dr. Rowe and Dr. Lowell have made an outstanding contribution with their excellent and comprehensive analysis of a large series of acetabular fractures. The literature abounds with impressions and recommendations from many authors whose ideas and conclusions are based on a small collection of cases, which in turn have been followed and studied over too short a period. Ninety-one patients with ninety-three acetabular fractures is a most substantial number, and with an average follow-up of six years, the authors can justifiably speak with authority. Their analysis, conclusions, and recommendations should be carefully studied by all who treat these sequelae of violent trauma.

It is unfortunate that in the orthopaedic literature there is no comprehensive or accepted classification of fractures of the acetabulum. Each author who attempts to report on any sizable number of these cases produces his own, and the current essayists are no exception. They have introduced several new terms in their classification. For example, they speak of bursting fractures, and of inner-wall fractures—this latter lesion has in most previous reports been called central dislocation. Key and Conwell speak of these as fractures of the pelvis. Charnley has advocated producing essentially this same condition as an accepted method of treatment in certain pathological conditions of the hip. Characteristically, the results in fracture-dislocations of the hip which involve only the inner wall are quite favorable. Twenty-nine hips (31 per cent) of Rowe and Lowell's cases were of this type, and regardless of how they were treated the results were never poor; they report 90 per cent *excellent* and *good* and 10 per cent *fair* in this group.

The real problems in fractures of the acetabulum result from severe trauma to the posterior and superior acetabular support and to neglected or prolonged displacement of the femoral head. Funsten, in 1938, pointed out that, "the longer the hip stays out of place, the poorer are the prospects of obtaining a satisfactory result by operation". Thompson and Epstein, in 1951, in their excellent report from the Los Angeles County Hospital, corroborated this fact. In 1952 we studied 193 cases and obtained adequate follow-up of 128 cases at the Campbell Clinic. There were no excellent or good results in any of the ninety cases treated by manipulative reduction if the hip had been displaced for as long as twenty-four hours. Now we find Dr. Rowe and Dr. Lowell again emphasizing the importance of early replacement of the femoral head into the acetabulum. In those cases with disrupted posterior acetabular rims, it seemed to be of little importance as to when the posterior fragments were fixed at open reduction (if necessary), provided the hip was reduced early and secured.

The next most important feature of reductions as so ably re-emphasized here today is the securing of a good relationship between the superior dome of the acetabulum and the weight-bearing portion of the femoral head. If one can properly align these parts and secure a stable posterior acetabular rim, then one can disregard to a great extent many of the other fragments and deformities seen on the roentgenogram. It is essential that no weight-bearing be allowed until the acetabular fractures are united; these require about three months. However, on the contrary, in minor fractures or in simple dislocations with fracture there is no contraindication to early weight-bearing, that is, after two or three weeks.

It is interesting that in most large series of cases which have been comprehensively studied concerning any specific disease or injury there will be a marked parallel and similarity of results and conclusions. So it is in comparing our cases with those reported by Dr. Rowe and Dr. Lowell. The distribution of cases as to age and sex was practically identical: the length of follow-up study was very similar; the per cent of patients with sciatic-nerve injury was the same; the number of patients in whom avascular necrosis and degenerative arthritis developed were about equal and were the result of the same conditions. Furthermore, it is interesting to note that from the study of the roentgenograms of our cases and those of the essayists', the clinical result was often superior to what should be expected from the final anatomical and roentgenographic findings. This fact is not new to you nor to the literature, but for those surgeons who would strive to obtain roentgenographic perfection it is worth repeating.

I would like to ask Dr. Rowe and Dr. Lowell what part they think postinjury muscle rehabilitation about the hip contributes to the final result after fracture of the acetabulum? In our study a major factor in improvement of the hip appeared to be the result from increase in the strength and function of the muscles controlling the joint. It was observed repeatedly in our patients that

(Continued on page 92)

Anterior Transplantation of the Posterior Tibial Tendon for Persistent Palsy of the Common Peroneal Nerve

BY PAUL R. LIPSCOMB, M.D., AND JAMES J. SANCHEZ, M.D., ROCHESTER, MINNESOTA

From the Mayo Clinic and Mayo Foundation, * *Rochester*

The procedure of stabilization of the foot and transfer of the posterior tibial tendon to the dorsum of the foot for the treatment of irreparable damage to the common peroneal nerve has been reported only infrequently [2,3,14,15,16]. Yet, the injury is relatively common and the procedure gives very satisfactory results. Of the 3,656 reported injuries to peripheral nerves in American military personnel in World War II, 745 (about 20 per cent) involved the peroneal nerve or peroneal fibers of the sciatic nerve [12]. In civilian practice peroneal palsy is most commonly the result of injury at the level of the knee or in the leg. However, permanent injury of the sciatic nerve, particularly of its peroneal portion, is rather common after traumatic dislocation and fracture-dislocation of the hip. Repair of the lateral popliteal (common peroneal) nerve does not give consistently satisfactory results. Useful motor recovery after repair of the common peroneal nerve occurred in only 36 per cent of the seventy-two patients reported by Clawson and Seddon [2].

We wish at this time to re-emphasize that triple arthrodesis and anterior transfer of the posterior tibial tendon may have much to offer patients who have persistent paralysis after injury of the peroneal nerve.

It is the purpose of this paper to review our experience at the Mayo Clinic with ten patients (Table I) having post-traumatic palsy of the peroneal nerve, on whom we performed transplantation of the posterior tibial tendon to the dorsum of the foot, together with stabilization of the foot by triple arthrodesis. All patients but one (Case 9) had complete palsy of the common peroneal nerve; in Case 9 there was slight function in the anterior tibial and peroneal muscles, but the patient could not dorsiflex the foot prior to tendon transfer. Of the ten patients whose cases were reviewed, seven were operated on by one of us (P. R. L.).

METHOD

Ober described the technique of bringing the posterior tibial tendon around the medial side of the tibia and through the anterior tibial compartment, drawing it distally in such a way that muscle fibers rather than tendon are in contact with the tibia. In our series, the tendon was freed, along with the lower fibers of the posterior tibial muscle, not only distally but also in the middle of the leg. The tendon was then passed medially around the tibia and, subcutaneously, across the ankle in eight patients and through the anterior tibial sheath in two patients, rather than through the interosseous membrane, as was advocated by Putti and, more recently, by Watkins and associates. Transplantation of the posterior tibial tendon in a long spiral course around the medial surface of the tibia is an easier and safer surgical procedure than transplantation through the interosseous membrane. If the surgeon pays attention to the details of the procedure described by

* The Mayo Foundation, Rochester, Minnesota, is a part of the Graduate School of the University of Minnesota.

Ober, a physiological direction of pull of the tendon can be achieved, and the tendon is not likely to adhere to the tibia or deep fascia. Although Ober passed the tendon through the anterior tibial sheath, and Mayer [4-8], through the sheath of the extensor digitorum longus, we prefer to place the tendon subcutaneously. We have had no particular difficulty with adhesion of the tendon to surrounding structures when it is in a subcutaneous position.

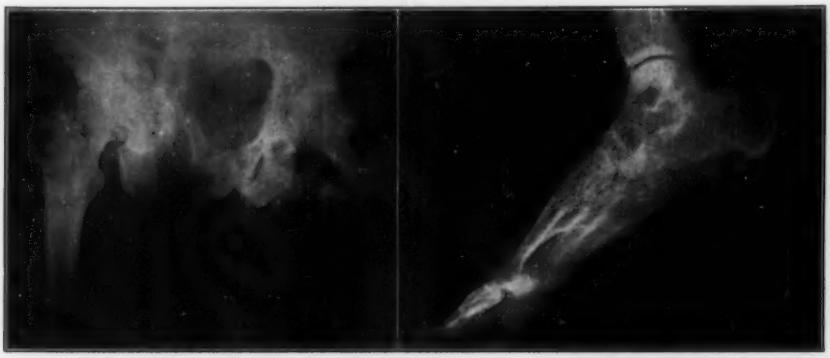

FIG. 1-A FIG. 1-B

Fig. 1-A: Case 3. Anteroposterior roentgenogram of the hip on the day of injury, which resulted in persistent palsy of the peroneal component of the sciatic nerve.

Fig. 1-B: Lateral roentgenogram of the foot six months after arthrodesis of the subtalar, talonavicular, and calcaneocuboid joints, and anterior transplantation of the posterior tibial tendon.

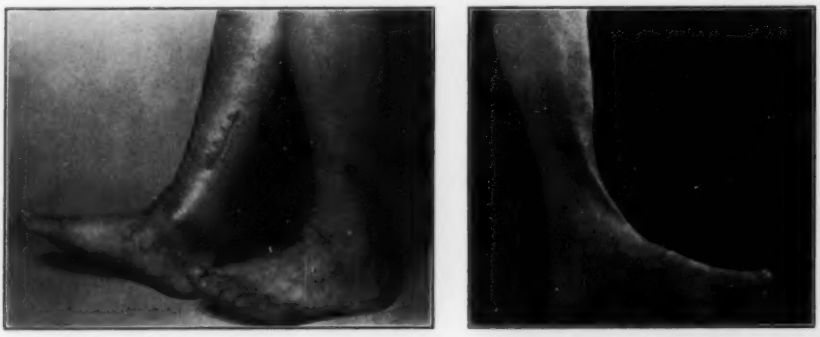

FIG. 1-C FIG. 2

Fig. 1-C: One year after anterior transplantation of the posterior tibial tendon around the tibia, the patient is able to dorsiflex the foot while standing. Note the appearance of the tendon over the anterior aspect of the ankle.

Fig. 2: Case 10. One year after anterior transplantation of the posterior tibial tendon around the tibia, the patient is able to dorsiflex the foot. (The extensor hallucis longus tendon was caught in scar resulting from the original injury.) Note how the transplanted posterior tibial tendon stands in relief over the anterior aspect of the ankle; the entire course of the tendon is outlined.

In one patient (Case 9) arthrodesis of the subtalar, talonavicular, and calcaneocuboid joints was done as a separate surgical procedure two months prior to the tendon transplant. In nine of the patients, tendon transfer was combined with triple arthrodesis (fusion of the three joints just mentioned).

Arthrodesis was done through two incisions since a medial incision had to be made anyway to sever the posterior tibial tendon near its insertion. The tendon was withdrawn through a third incision in the middle third of the posteromedial aspect of the leg. The muscle was freed proximally almost to the point where it received its innervation and was then rerouted over the medial surface of the tibia

TABLE I

CASE HISTORIES OF TEN PATIENTS WITH ANTERIOR TRANSPLANTATION OF THE POSTERIOR TIBIAL TENDON FOR PERSISTENT PALSY OF THE COMMON PERONEAL NERVE

Case No., Sex, and Year of Injury	Cause of Injury and Associated Fractures *	Site of Injury	Previous Surgical Procedures for Injury and Date	Date of Tendon Transfer and Age at Transfer	Method of Transfer and Associated Surgery	Type and Duration of Postoperative Immobilization	Length of Follow-up and Result	Comment
1, F, 1936	Thrown by horse; fracture of upper part of femur	Left buttock	Lumbar sympathectomy for vasospasm, 1940; exploration and neurolysis of sciatic nerve in buttock, 1941	May 1943, 21 yrs.	Around tibia and into cuboid; triple arthrodesis	Cast, 3 mos.	4 yrs., poor	Patient originally had complete sciatic-nerve palsy; posterior tibial was very weak when transferred and never functioned; Campbell bone-block in 1947
2, M, 1948	Struck by car; dislocation of hip	Left buttock	Exploration of sciatic nerve (no gross abnormality noted), 1949	June 1953, 14 yrs.	Around tibia to middle cuneiform; triple arthrodesis	Cast, 3 mos.	6½ yrs., good	Posterior tibial slightly weak at time of transfer
3, M, 1956	Automobile accident; fracture and dislocation of hip	Right buttock	Arthrodesis of hip, 1958	Dec. 1958, 55 yrs.	Around tibia to middle cuneiform; triple arthrodesis	Cast, 3 mos.	1½ yrs., good	Patient has good gait despite arthrodesis of hip
4, F, 1943	Tripped and fell; severe ligamentous injury of knee	Right knee	Neurolysis of peroneal nerve, 1944	Oct. 1944, 21 yrs.	Around tibia and through anterior tibial sheath to base of third metatarsal; triple arthrodesis	Cast, 3 mos.; brace, 3 mos.†	6 mos., good	Patient lost to follow-up in 1945
5, M, 1934	Football injury; compound supracondylar fracture of femur	Upper part of popliteal space on left	Drainage of several abscesses for chronic osteomyelitis, 1934 to 1941; sequestrectomy, 1941	Aug. 1947, 33 yrs.	Around tibia to lateral side of navicular; lengthening of tendo achillis; triple arthrodesis	Cast, 3 mos.	11 yrs., good	Ankylosis of knee as a result of injury and osteomyelitis which followed

6, F, 1942	Crossed-leg palsy and possible protruded disc	Right knee	None	Nov. 1949, 43 yrs.	Around tibia to medial cuneiform; triple arthrodesis	Cast, 3½ mos.	10 yrs., good	Clinical picture for peroneal-nerve palsy was typical except for fact that tendo achillis reflex was also absent
7, M, 1930	Struck by truck; dislocation of hip and leg	Left knee and upper fibula	?	Oct. 1944, 24 yrs.	Around tibia and through anterior tibial sheath to lateral cuneiform; triple arthrodesis	Cast, 2 mos.; brace, 3 mos.†	5½ mos., fair	No reply to follow-up query; patient had good motion but had difficulty remembering to use transferred muscle
8, F, 1954	Struck by bumper of car; compound fracture of fibula and avulsion of peroneal nerve	Upper part of right leg	Débridement, 1954	Oct. 1954, 27 yrs.	Around tibia to middle cuneiform; triple arthrodesis	Cast, 3 mos.	3½ mos., good	Peroneal nerve explored and gap of 4 to 5 inches with much scarring was found; we proceeded immediately with tendon transfer and stabilization
9, M, 1941	Scuffling and fall; severe ligamentous injury of knee	Left knee	Neurolysis, 1942	Feb. 1951, 38 yrs.	Around tibia to middle cuneiform; triple arthrodesis performed 2 mos. prior to tendon transfer	Cast, 2 mos. for triple arthrodesis and 1 mo. for tendon transfer; brace, 3 mos.†	5 yrs., good	Slight return of function in anterior tibial and peroneal muscles following neurolysis 10 mos. after injury
10, M, 1958	Caught leg in grain auger	Side of left leg	Débridement and primary split-thickness skin graft, 1958; flap graft from posterior thigh to side of leg, 1959	June 1959, 31 yrs.	Around tibia to middle cuneiform; triple arthrodesis	Cast, 3 mos.	1 yr., good	Peroneal nerve and muscles were torn out from entire lateral side of leg; still complains of some pain in medial side of foot; tenodesis of extensor hallucis longus tendon limits plantar flexion to 15 degrees; talonavicular joint did not fuse and will probably require bone graft; walks with hardly a limp

* All patients had reduction of fracture or dislocation.

† Leg brace used was the short, double-iron, 90-degree, ankle-stop type.

at the juncture of the upper and middle thirds of the leg. The tendon was then passed subcutaneously to the mid-line of the dorsum of the foot, where it was inserted, in most cases, into one of the cuneiform bones. In Case 4 it was inserted into the base of the third metatarsal; in Case 5, into the navicular; and in Case 1, into the cuboid. The tendon was most often fixed into the middle cuneiform bone and was generally held with a Bunnell pull-out wire suture. In a patient with a fixed equinus deformity, the tendo achillis was lengthened during the same surgical procedure through a fourth incision.

After operation, the limbs were usually immobilized in a plaster-of-Paris leg cast which extended from the base of the toes to the tibial tubercle, with the foot held at a right angle. The cast was worn for from three to four months. Four of the patients for an additional three months used a leg brace with double uprights and a posterior stop to hold the foot at a right angle. On removal of the cast, all patients were given instruction in the department of physical medicine in exercises to educate the transferred muscle in its new function as a dorsiflexor. Prolonged supervised rehabilitation was not the rule, however.

RESULTS

All but one of the patients were judged to have satisfactory dorsiflexion of the foot (Figs. 1-A, 1-B, 1-C). The one patient (Case 1) whose transfer did not function had originally had complete paralysis of the sciatic nerve, and the posterior tibial muscle was still weak seven years after injury; this patient later had a Campbell posterior bone-block inserted to prevent foot-drop. One of the patients whose transfer was routed across the ankle through the anterior tibial tendon sheath (Case 7) was judged to have a fair result. He had good voluntary motion and strength for dorsiflexing the foot after the tendon transfer; but, when last seen five and one-half months after operation, he used the transferred tendon while walking only when he made a conscious effort to do so.

The patients who were judged to have good results could dorsiflex the foot to 90 degrees (or within 10 degrees of this extent) and could extend (plantar flex) the foot approximately 20 or 30 degrees (to 110 or 120 degrees). These patients had slight or minimum limp when walking on a level surface. Almost all patients had more calluses on the foot of the affected leg than on that of the normal leg, but the calluses seemed to give only minimum difficulty. The triple arthrodesis was solidly fused in all except one patient (Case 10). Because of the failure of fusion of the talonavicular joint, this patient was judged to have a fair result, although the tendon transfer functioned very satisfactorily (Fig. 2). The stabilization procedures no doubt contributed immeasurably to the results. Unless the patient is too young for triple arthrodesis, transplantation of the posterior tibial tendon should probably always be combined with stabilization of the foot. The use of a brace for three months after immobilization in a cast did not seem to enhance the results.

In a recent follow-up query to which six of the ten patients responded, each was asked if he thought that his condition had been improved by the surgical procedure. All stated definitely that the surgical procedure had produced appreciable improvement.

COMMENT

As a result of dangers of modern travel and the increasing use of industrial machines, it is reasonable to assume that the number of persons sustaining irreparable damage to the peroneal component of the sciatic nerve or to the common peroneal nerve itself will increase. Patients with complete paralysis of this type

are left with intact function of the plantar flexors and posterior tibial muscles but no function of the dorsiflexors and evertors of the foot. The only tendon with muscle power intact which can or should be used to restore dorsiflexion of the foot is the posterior tibial. We have found that transfer of the posterior tibial tendon around the medial side of the tibia is a very satisfactory method. This transfer is easier and is less likely to damage the tibial nerve, the one remaining functioning motor nerve, than transfer of the tendon through the interosseous membrane. It is important when doing the medial transfer that the tendon and lower muscle fibers be freed adequately; that muscle fibers, rather than tendon, lie in contact with the bone; and that the pull of the muscle-tendon unit be in a long spiral or oblique direction. In our experience, it seemed to matter little into which of the tarsal bones the tendon was inserted, but in all of our patients the foot was stabilized by arthrodesis of the talocalcaneal, calcaneocuboid, and talonavicular joints. We believe that stabilization of the foot is an important part of the treatment.

Möllerud advocated attaching the tendon far back on the dorsum of the foot —that is, near the axis of movement—in an attempt to amplify the range of movement. Biesalski and Mayer stated that the posterior tibial tendon has an amplitude of only two centimeters, whereas the dorsiflexors (the anterior tibial and extensor hallucis longus tendons) have amplitudes of from three to five centimeters. Milgram declared that the average weight of the anterior tibial muscle and tendon is 122 grams and that of the posterior tibial, seventy-eight grams. There seems to be little question of the ability of the posterior tibial muscle to provide strong dorsiflexion of the foot. It was probably because of the limited excursion of the tendon that only 15 to 30 degrees of active motion at the ankle joint was obtained after tendon transfer in the patients in this series. We hasten to add that this is a useful range of motion and, for ordinary walking on a level surface, has allowed most patients to walk with hardly any limp. Only one of the patients in this series had the stabilization and tendon transfer performed by a two-stage operation; it seems to us that both procedures can and should be combined in the majority of instances. In a child who is too young for arthrodesis, the transfer may be done when the lesion of the peroneal nerve is judged to be irreparable, and the stabilization, if still necessary, may be postponed until puberty.

SUMMARY

The results of anterior transfer of the posterior tibial tendon for peroneal palsy secondary to trauma in ten patients treated at the Mayo Clinic have been reviewed and analyzed. In all patients the tendon was transferred in a long spiral manner around the medial surface of the tibia to the dorsum of the foot and triple arthrodesis was performed.

The results of this study re-emphasize that transfer of the posterior tibial tendon to the dorsum of the foot satisfactorily restores the ability to dorsiflex the foot when persistent palsy of the common peroneal nerve is present. Transfer of the posterior tibial tendon around the medial side of the tibia, rather than through the interosseous membrane, gives satisfactory results if the original technique described by Ober is adhered to. Transfer of the posterior tibial tendon should be accompanied by stabilization of the foot, except, perhaps, in the young child. Persistent palsy of the common peroneal nerve is comparatively frequent. The annoying equinovarus gait or the use of a drop-foot brace can be eliminated in most instances by anterior transplantation of the posterior tibial tendon combined with triple arthrodesis.

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Myxoma of Bone in Childhood

BY O. SCAGLIETTI, M.D., AND G. STRINGA, M.D., FLORENCE, ITALY

From the Istituto Ortopedico Toscano dell' Universita di Firenze, Firenze

Two cases of a rare bone tumor were recently observed in the Orthopaedic Institute of Tuscany. Three similar cases, which we reported previously, will also be referred to in order to demonstrate certain characteristics common to all five. In recent literature this type of tumor was called *chondromyxoid fibroma*, as defined by both Jaffe and Lichtenstein. However, in our opinion, the five cases reported here, as well as some of the cases reported by Jaffe, Lichtenstein, and Dahlin, constitute a separate group distinguishable from typical chondromyxoid fibromata because of certain clinical and morphological characteristics which may influence the surgeon to employ different therapeutic measures. The purpose of the present communication is to stress the characteristics that distinguish these tumors from the classic form described in the literature.

CASE REPORTS

CASE 1. M.L., a ten-year-old girl, had complained of pain in the hip, had limped, and had had restriction of hip motion for four months. During the month preceding admission the pain had become severe. Physical examination revealed a firm, rather tender mass in the trochanteric region. Roentgenograms (Fig. 1-A) showed an area of osteolysis eccentrically located in the upper one-third of the femoral diaphysis and in the distal portion of the greater trochanter. The part of the lesion in the diaphysis had a distinct margin, with a narrow surrounding zone of sclerotic reaction. The lateral cortex of the femur was destroyed, and the lesion had spread beyond the limits of the bone, as was shown by a narrow outline of subperiosteal ossification. An intense periosteal reaction was evident just below the distal end of the lesion. The bone produced by this reaction had almost tripled the thickness of the normal cortex, forming a triangular mass of dense bone. A diagnosis of myxoma of childhood was made and because of our previous experience a total resection of the lesion was performed in April 1958. A strip of cortical bone, taken from the contralateral tibia, was inserted as a bone graft to ensure restoration of continuity of the femur.

After the limb had been immobilized in a plaster spica for five months, the graft had developed sufficiently to indicate that the lesion had been eradicated. Clinical and roentgenographic examination at this time indicated that the over-all result was excellent (Fig. 1-B). The patient has now been followed for two years with no evidence of recurrence.

The resected fragment (Fig. 1-C) contained a fairly soft, gelatinous, grey mass eccentrically located in the diaphysis; the mass was sharply demarcated from the spongiosa by a continuous border of sclerotic bone and from the soft parts by the periosteum and irregular areas of subperiosteal bone. At the distal end of the mass, the cortex was enormously thickened—the result of the periosteal reaction.

On histological examination (Figs. 1-D, 1-E, and 1-F), staining with hematoxylin and eosin revealed myxoid tissue characterized by the presence of stellate and elongated cells surrounded by an abundant intercellular substance. This myxoid tissue was arranged in lobules with a layer of proliferating cells at the periphery of each lobule. The toluidine-blue stain (Fig. 1-G) revealed a distinctly metachromatic reaction in the intercellular substance.

CASE 2. P.P., a ten-year-old boy, had been seen previously in another hospital because of pain in the left knee. The pain, which had been present for two months, was getting worse; examination showed that the knee was exquisitely tender. A roentgenogram (Fig. 2-A) revealed an eccentric lytic lesion with destruction of the lateral cortex of the lower femoral diaphysis and involvement in a limited area of the adjacent spongiosa. There was a slight periosteal reaction, and the lesions showed some tendency to spread beyond the limits of the bone into the soft tissue. Curettage was carried out at the other hospital in September 1957 and the soft, greyish tissue obtained proved, on histological examination, to be myxomatous. This tissue was stained only with hematoxylin and eosin.

Fig. 1-A

Fig. 1-B

Figs. 1-A through 1-G: Case 1, M. L., a ten-year-old girl, whose symptoms had started four months before admission.

Fig. 1-A: Roentgenograms showing eccentric, extracortical localization and marked periosteal reaction. Treatment consisted in resection of the affected segment, followed by an autogenous-bone graft.

Fig. 1-B: Two years after operation.

Fig. 1-C

Frontal section through the resected fragment showing the eccentric, extracortical localization of the neoplasm and the thickness of the cortical layer distal to the tumor. The cortex here is almost three times the normal thickness.

Eight months after the first operation the child was seen in our hospital because of recurrence of pain in the knee; examination now showed a small, quite localized, quite tender swelling on the lateral aspect of the knee. Roentgenograms (Fig. 2-B) showed that in the outer half of the femoral metaphysis, the site of the previous surgical procedure, there was diffuse sclerosis in which circular areas of rarefaction could be observed. In addition, there was an oval mass that extended beyond the normal lateral and posterior contours of the bone and was surrounded by a thin border of periosteal new bone—a sign of recurrence.

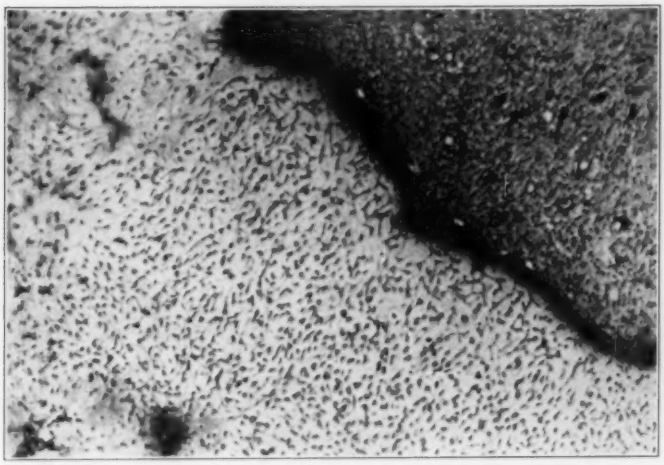

FIG. 1-D

Low-power histological section. The tumor tissue is represented by scarce stellate or triangular cells in abundant ground substance. The fibrous-tissue reaction in the medullary layer, compressed by the tumor lobules, can be seen in the upper right-hand corner, outside the proliferative layer. It appears that this fibrous tissue almost constitutes the stroma of the tumor (hematoxylin and eosin).

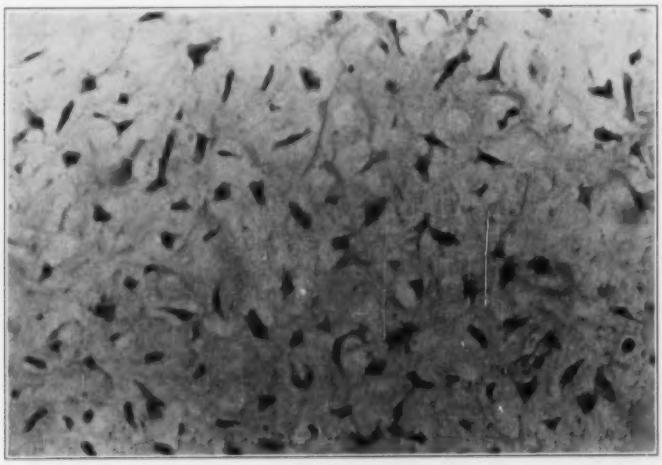

FIG. 1-E

Higher power histological section. The ground substance is homogeneous, without large lacunae or vacuoles and without distinct fibrillary images (hematoxylin and eosin).

In June 1958 the patient was treated by wide excision of the affected portion of the femur with removal of the lateral half of the metaphysis down to the epiphyseal cartilage plate. The defect created in this way was bridged by two strips of autogenous cortical bone obtained from the tibia. Section of the resected fragment revealed lobules of soft, greyish tissue contained within numerous compartments of sclerotic bone. As in the first case, this lesion was composed of large lobules, each one well circumscribed and visible on gross examination, but in this case the lobules were spread thinly throughout a large part of the metaphysis. Histological examination (Figs. 2-D and 2-E) revealed, as in the previous case, myxomatous tissue arranged in lobules, each lobule surrounded by a peripheral layer of proliferating cells. Staining with toluidine blue showed distinctly positive metachromatic reaction in the intercellular substance. The limb was immobilized in a plaster cast for four months; no further immobilization was used. A roentgenogram made one year after the

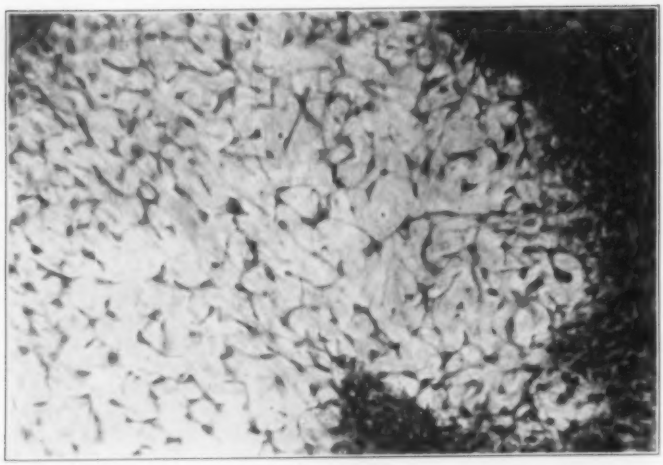

FIG. 1-F

Histological section showing a few myxomatous stellate cells. The proliferative layer of cells is shown in more detail at the right (hematoxylin and eosin).

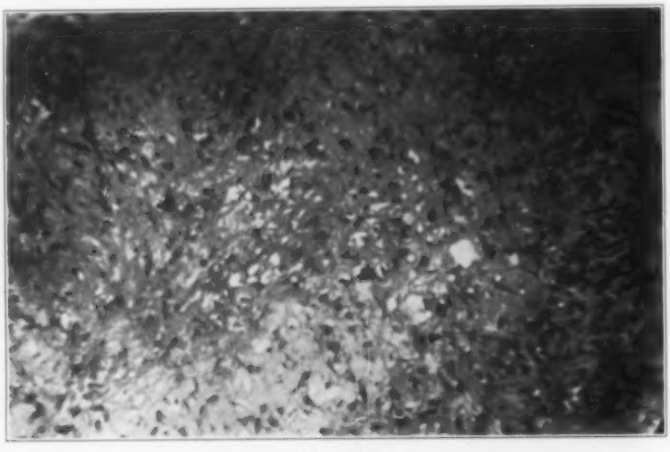

FIG. 1-G

Microphotograph of section stained with toluidine blue to demonstrate metachromasia. The nuclei and cytoplasm of the cells are stained blue; there is not much ground substance at the periphery of the tumor because of the density of the cells. The ground substance present in the center of the lobule in considerable quantities stains a clear red, indicating metachromasia.

second operation (Fig. 2-C) showed areas of rarefaction surrounded by a sclerotic border in the part of the metaphysis that had previously been normal; these findings suggested a second recurrence, developing after incomplete excision. There was also arrest of growth of the lateral part of the distal femoral epiphysis and some valgus deformity. Immediate excision of this recurrent lesion was indicated and the patient was again operated on.

These two cases have certain characteristics in common with the three other cases we reported [7]. Summarized very briefly these cases were as follows:

D.T., a boy, five years old, had pain in the left knee for one month before admission. Roentgenograms (Fig. 3-A) showed a round radiolucent lesion in the upper one-third of the tibia, eccentrically placed in the posterolateral portion of the metaphysis. The lesion was treated by curettage. The gross and histological characteristics of the tissue removed (Fig. 3-C) were similar to those

FIG. 2-A

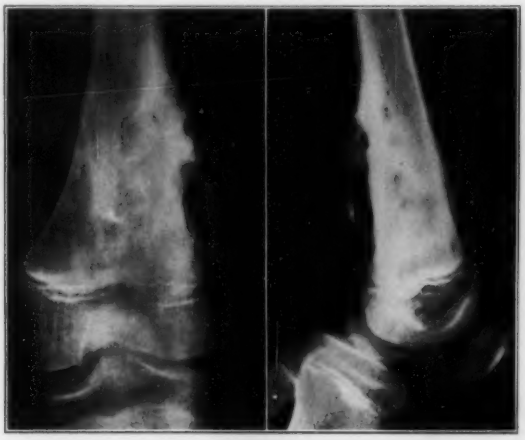

FIG. 2-B

Figs. 2-A through 2-E: Case 2, P. P., a ten-year-old boy, whose symptoms had started two months before admission to another hospital.

Fig. 2-A: Roentgenogram showing an eccentric lytic lesion and bone reaction around the periphery of the lesion. Curettage had been done at another hospital, where the microscopic examination had revealed myxomatous cells.

Fig. 2-B: Roentgenograms made on admission to our hospital, eight months after the first operation, show local recurrence. Treatment consisted in partial resection and an autogenous-bone graft.

Fig. 2-C: One year after the second operation there is new local recurrence, as shown by the central rounded radiolucent area.

FIG. 2-C

described in Cases 1 and 2. The lesion recurred three months after curettage and continued to progress, despite roentgen therapy (Fig. 3-B). Mid-thigh amputation was performed one year after curettage. The patient was not seen again.

C.M., a six-year-old boy, was hospitalized because of pain in the ankle for twenty days. Roentgenograms revealed a lytic lesion in the lower tibial metaphysis (Fig. 4-A). Six months after curettage the lesion recurred; one year after curettage the lesion was resected and a bone graft inserted.

Gross and histological examination of the lesion revealed myxoid tissue similar to that found in the other cases. This child was living and well, with no evidence of recurrence nine years later (Fig. 4-C).

M.S., a boy, five years old, was hospitalized because of pain in the hip for forty days before admission. Roentgenograms revealed a round osteolytic lesion in the upper femoral metaphysis (Fig. 5-A).

Curettage was followed by recurrence six months later. Two years after curettage (Fig. 5-B) the lesion was resected and bone grafts were inserted. Twenty years after operation this patient was well, without evidence of recurrence. The gross and histological examinations of this lesion gave results similar to those in the previous cases.

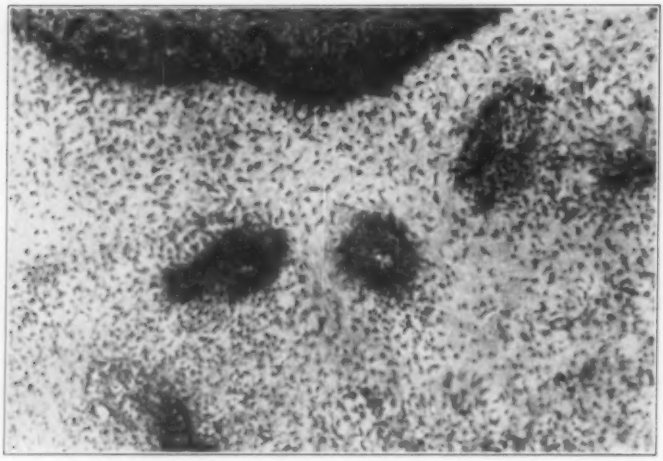

FIG. 2-D

Low-power photomicrograph; note the similarities to Case 1.

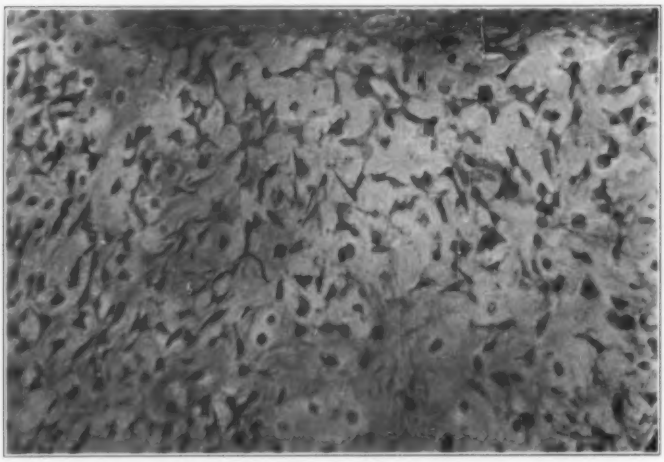

FIG. 2-E

High-power photomicrograph; note the sparse cells in an abundant and uniform ground substance.

CLINICAL AND LABORATORY FINDINGS

Age

All five patients were in the first decade of life: ten, ten, five, six, and five years; an average of 7.2 years.

Course and Symptoms

In all patients pain, swelling, and restriction of function developed rapidly; only three to six weeks elapsed between the appearance of the first subjective signs and operation. The symptoms were severe in all.

Roentgenographic Characteristics

The lesion in every instance made its appearance as a radiolucent round or

FIG. 3-A

FIG. 3-B

Figs. 3-A through 3-C: D. T., a five-year-old boy, had had severe symptoms for one month prior to admission.

Fig. 3-A: Roentgenograms showing an eccentrically located oval lesion with marked periosteal reaction. Curettage was performed by V. Putti and histological sections showed the tumor to be a myxoma. (Reproduced with permission from "Mixoma periostale dell'infanzia e condroma periostale dell'adolescenza a malignitá locale", by O. Scaglietti and G. Stringa. Arch. "Putti", **7**: 13–39, 1956.)

Fig. 3-B: Appearance of recurrence one year after curettage. (Reproduced with permission from "Mixoma periostale dell'infanzia e condroma periostale dell'adolescenza a malignitá locale", by O. Scaglietti and G. Stringa. Arch. "Putti", **7**: 13–39, 1956.)

FIG. 3-C

Transverse section through segment removed from the tibia showing the completely eccentric position of the neoplasm. In a few areas the lesion appears to perforate the cortical layer from outside inward (with clear signs of osteoclasia) and infiltrate into the medullary canal. We believe that this neoplasm is extracortical and not central in origin. (Reproduced with permission from "Mixoma periostale dell'infanzia e condroma periostale dell'adolescenza a malignitá locale", by O. Scaglietti and G. Stringa. Arch. "Putti", **7**: 13–39, 1956.)

oval area. Around the lesion there was a marked tissue reaction characterized by subperiosteal new-bone formation, which, in some instances, increased the thickness of the cortical layer to as much as three times its normal thickness by thickening of the enveloping periosteum and by diffuse sclerosis of the underlying spongious bone (Figs. 1-A, 1-B, 3-A, 3-B, 3-C, 4-A, and 4-B). It should be emphasized that this roentgenographic appearance is that of a very active lesion which provokes an intense reaction in the tissues around it.

Morbid-Anatomical Findings

Although it cannot be established with certainty, this lesion appears to originate in the subperiosteal extracortical region and to penetrate the spongiosa

FIG. 4-A

FIG. 4-B

Figs. 4-A, 4-B, and 4-C: C. M., a six-year-old boy, had had pain in the ankle for twenty days before admission.

Fig. 4-A: Roentgenograms showing a lytic lesion in the lower tibial metaphysis. Meticulous curettage of this lesion was carried out. (Reproduced with permission from "Mixoma periostale dell'infanzia e condroma periostale dell'adolescenza a malignitá locale", by O. Scaglietti and G. Stringa. Arch. "Putti", **7**: 13-39, 1956.)

Fig. 4-B: Roentgenogram made seventeen months later showing extensive recurrence. Treatment consisted in resection of the entire diaphysis and bone-grafting. (Reproduced with permission from "Mixoma periostale dell'infanzia e condroma periostale dell'adolescenza a malignitá locale", by O. Scaglietti and G. Stringa. Arch. "Putti", **7**: 13-39, 1956.)

FIG. 4-C

FIG. 5-A

FIG. 5-B

Fig. 4-C: Follow-up roentgenogram, made nine years after operation.

Figs. 5-A and 5-B: M. S., a five-year-old boy, had had symptoms for forty days before admission.

Fig. 5-A: Initial roentgenogram showing a rounded lytic lesion extending throughout the intertrochanteric region (arrows). (Reproduced with permission from "Mixoma periostale dell'infanzia e condroma periostale dell'adolescenza a malignitá locale", by O. Scaglietti and G. Stringa. Arch. "Putti", **7**: 13-39, 1956.)

Fig. 5-B: Recurrence two years after curettage showing an extensive multilocular lesion. Treatment consisted in resection of the upper end of the femur. Histological studies revealed a myxoma. When last seen, twenty years after admission, the patient was well. (Reproduced with permission from "Mixoma periostale dell'infanzia e condroma periostale dell'adolescenza a malignitá locale", by O. Scaglietti and G. Stringa. Arch. "Putti", **7**: 13-39, 1956.)

of the metaphysis. Possibly, the thin cortex of the metaphysis and underlying spongiosa in these young children offer less resistance to growth of the tumor than the overlying firm periosteum and ligamentous structures. This site of origin

would explain the consistent eccentric intraspongious localization of these tumors, although some authors [4] interpreted this location to indicate a central origin. Some of our resected specimens (Figs. 1-C and 3-C) strongly suggest an extracortical origin and subsequent intraspongious invasion. Objection can be raised to the assumption that the tumor grows from within outward. We have specimens which show no involvement of the medullary canal, but in all specimens the periosteal response and the extracortical mass is impressive compared with the small intracortical mass. Why should the tumor, if of intracortical origin, perforate the cortex and project itself from within out and always develop on the outside? We believe that the contrary is true. The tumor is not encapsulated by a con-

FIG. 6

Non-osteogenic fibroma of bone. The patient, a ten-year-old girl, had had pain for one month after a minor fall.

The roentgenographic appearance is different from myxoma of bone. The lesion occupies a central position in the bone; there is no periosteal reaction, except at the site of the fatigue fracture, which passes through the neoplasm.

tinuous peripheral membrane, but consists of a collection of lobules; its periphery is demarcated only by the reaction of the normal host tissue. In the cases we personally observed, each mass was lobulated and greyish yellow. Although the lobules consisted of gelatinous material resembling that found in a ganglion, the whole mass was rendered quite stiff by the presence of the subdivisions or septa. With their soft, viscous character these lesions certainly resembled gelatinous cysts or ganglia more than cartilaginous lesions, which would ordinarily be firmer and of a mother-of-pearl appearance.

Histological Findings

Slight magnification and even examination with the naked eye revealed that the tumor was composed of round lobules. The periphery of each lobule consisted of closely packed round cells intermingled with the elongated, stellate, or triangular cells, which constituted the main part of the lobule. In isolated areas in the periphery of the lobules it was easy to find cellular polymorphism and nuclear irregularities with chromatin condensation. The appearance was not of degenerating cells, as can easily be discerned when the intercellular substance is edematous

and infiltrated with inflammatory cells, but of normal, vital cells. The stroma surrounding the lobules within the bone was made up of the cells and intercellular substance of the marrow of the invaded bone. In large microscopic sections of the whole lesion, the fibrous marrow close to the periphery of the tumor appeared to be compressed and more cellular. There was marked cellularity in the portions of the marrow actually enclosed by lobules of the tumor. It was frequently difficult to differentiate between compressed normal tissue and proliferating cells at the margin of the lobules (Fig. 1-F). Many giant cells were lined up along the border of the tumor in contact with the proliferating connective tissue just described. Because the giant cells appeared in the fibrous marrow, we had to call them foreign-body giant cells.

The intercellular substance of the tumor had a uniform, very thin, fibrillar appearance. Of particular interest was its reaction to metachromatic staining. We are aware of the technical difficulties which complicate the preparation and interpretation of microscopic slides for the demonstration of metachromasia. Variations of the pH may lead to color changes that may be erroneously interpreted as metachromasia. Certain structures, such as the collagen fibrils themselves, may show metachromatic staining under certain conditions. Using the technique of Lison, we stained our sections in 0.50 per cent solution of toluidine blue and mounted them in Canada balsam. With this technique the intercellular substance of the tumor appeared to be distinctly metachromatic because it stained red; only the nuclei stained blue (Fig. 1-G). Some of our histological preparations were submitted for assessment to Lison and other eminent histologists; it was Lison's opinion that there was indubitable metachromatic staining.

In view of this histochemical reaction we presume that the ground substance in these tumors contains sulphuric esters of high molecular weight, such as the chondroitin sulphates, which, specifically, give the metachromatic reaction [10]. With preliminary treatment with hyaluronidase the reaction disappears, thus demonstrating that the hyaluronic acid plays no part in the reaction. Among other stains, alcian blue was used: it stained to a low degree and very irregularly in some zones. The difficulty of understanding the chemical and physical meaning of the various methods of staining and classifying mucopolysaccharides and proteins led us to avoid further interpretation of this finding.

This staining reaction and the other characteristics of this tumor, both clinical and morphological, led us to classify these neoplasms as myxomata.

Clinical Development and Response to Treatment

The pronounced symptomatology and rapid progression of these tumors necessitated immediate operation in all our patients. In four of the five children a careful curettage had been carried out by fully qualified surgeons *, but there were recurrences in from three to eight months (Figs. 2-A, 3-A, 3-B, 4-A, 4-B, 4-C, 5-A, and 5-B). The recurrences were so intense and had progressed so rapidly that the more radical procedure of resection was done. Some of the patients treated by resection were followed more than five years and were found to be completely symptom-free.

The consistently rapid recurrence in all of these cases is an important characteristic of this lesion that should be kept clearly in mind. The aggressive nature and tendency to recurrence are typical characteristics of myxomata. The tumors have long been known to recur frequently and to show a tendency to infiltrate and destroy adjacent tissues.

* Dr. V. Putti and Dr. F. Delitala.

CHARACTERISTICS OF CHONDROMYXOID FIBROMA

If we review the characteristics of chondromyxoid fibroma as they have been set forth in the principal publications on the subject, we find that they differ, in many respects, from the characteristics of the five tumors described here. We shall attempt to discuss and interpret some of these differences.

Age

Jaffe said that chondromyxoid fibroma never develops in a very young child, and that two-thirds of all of the lesions he had seen were in patients between ten and thirty years of age. Lichtenstein, also, noted that this lesion was most common in the second and third decades of life. Iwata and Coley, in reviewing the literature, found thirty-six cases and only one was in a patient under nine years of age. Of the twenty-eight cases discussed by Dahlin, 55 per cent were in patients in the third decade of life. It is apparent, therefore, that our patients were younger than those reported in the literature. We believe that age may constitute one of the first criteria that differentiate our five cases and the few cases [1,3,4,5] in which the patients were about ten years old or younger. In these instances the tumors seemed to have different characteristics from those observed in persons between thirty and fifty years of age.

Course and Symptoms

In the literature concerning chondromyxoid fibroma, mention is made of its rather protracted symptomatology. This often dated back months or even years and was characterized either by mild disturbances or even by no symptoms at all in the cases discovered only by accident. On the other hand, in our cases the evolution was quite rapid.

In the cases reported in the literature, the progression of the lesion was more rapid in younger patients. This agrees with our viewpoint, that in young patients these lesions show a more rapid course and appear to be different from those with a slow course or those diagnosed fortuitously.

Roentgenographic Appearance

In the literature it is stated that the roentgenographic appearance of chrondromyxoid fibroma suggests an inactive lesion, showing only expansion of the cortical layer. In a few of the reported cases, usually in children, there was a periosteal reaction and diffuse cortical thickening extending for a considerable distance from the lesion. These changes were always observed in children. In our opinion, lesions with these characteristics are to be distinguished from the others.

Histological Characteristics

It is stated in the literature that chondromyxoid fibroma does not give a positive metachromatic reaction [4]. This is in contrast to our findings. In attempting to explain this difference we have considered the possibility that the lesions in the cases we reported are similar, but being in children, they are more active, more aggressive neoplasms. Sylvén [10] showed that the sulphuric-ester content of the same myxoma varies with the biological state of the tumor tissue. The esters, and hence the metachromasia, are abundant in growing areas, but they show a decrease that parallels the decreased growth tendency of the older and more mature tumor tissue. As a rule, the central areas of a myxoma show either no metachromatic staining at all or only a weak reaction. We believe that the cases in the literature in which the metachromatic test was carried out with negative results are variants of the type of tumor reported here; variants occurred in older patients with a less pronounced tendency toward growth.

Another point to be stressed concerns the presence of chondroid areas. In our cases there were no large, widespread, or even predominant areas of chondroid or cartilaginous cells, as described in the cases reported and illustrated in the literature. In our histological preparations the cells showed, in a few isolated regions, some tendency to be round, but the round cells were always intermingled with cells of typical myxoid appearance. All these different cells were surrounded by identical intercellular substance. These modifications in the appearance of the cells in the cases reported in the literature can be readily explained since it is known that fibromatous characteristics may develop in a myxoma, either spontaneously or after irradiation. An older or more mature myxoma may assume a structural appearance similar to a fibroma to the extent that it is justifiable to apply the term *fibromyxoma* to it. Since the tumor in question is of skeletal origin and its structure closely resembles that of embryonal connective tissue, it is reasonable to assume that it has the potential capacity to produce skeletal tissue or chondroid as it becomes older and loses its initial aggressiveness. In the lesions that occur later in life the fibrochondromatous components may predominate over the myxoid component.

Evolution and Therapy

According to the opinions advanced in most reports chondromyxoid fibroma is entirely benign, has no tendency to recur, and can be treated efficaciously with curettage. It is perhaps significant in this connection that the only cases with recurrences reported by Jaffe were in two patients aged thirteen and seventeen years, respectively; the one case with chondrosarcomatous degeneration reported by Iwata and Coley occurred in a patient seventeen years old. In other words, the reported cases that did not follow a benign course occurred in younger patients, whose ages were nearer to those of our patients. Because the tumor is more aggressive in the younger patient it would appear that the younger the patient, the more readily and, perhaps, more consistently will there be recurrence.

Differential Diagnosis

The clinical and roentgenographic characteristics of the cases we observed so far have been consistent and have always permitted a definite diagnosis. Of interest from the point of view of differential diagnosis is the following case. Its characteristics resembled those of the type of myxoma being reported here, but there were certain differences that made it possible to distinguish this case from those reported here.

The patient, a ten-year-old girl, had had an injury one month before admission. She complained that while walking she noted a circumscribed painful spot in the leg. There was no visible or palpable swelling. Roentgenograms revealed a multilocular radiolucent lesion in the upper metaphysis of the tibia, centrally located in the bone and delimitated by a festooned sclerotic border (Fig. 6). A healed fracture line passed transversely through the tibia at the level of the lesion. A moderate periosteal reaction had caused thickening of the cortical layer. This thickening was maximum at the level of the fracture; the roentgenogram suggested a healing fatigue fracture. Although the roentgenograms were suggestive of myxoma of bone, there were certain clinical and roentgenographic features that prevented making such a diagnosis: (1) the slight local pain and swelling; (2) the central position of the lesion in the bone; and (3) the insignificant periosteal reaction, no more than could be explained by the fatigue fracture. Histological examination of tissue from the lesion revealed fibrous tissue with sparse giant cells typical of non-osteogenic fibroma of bone.

CONCLUSIONS

It has been stated in the literature that chondromyxoid fibromata develop, as a rule, in the third decade of life; cause few symptoms; progress slowly; consist of myxoid, chondroid, and cartilaginous tissue; do not give a positive metachromatic reaction; and can be cured, without risk of recurrence, with simple curettage. We encountered five cases so similar to these tumors that most investigators would class them as chondromyxoid fibromata, but they have certain characteristics that distinguish them from the ones discussed in the literature. Although some might favor classifying these five cases as chondromyxoid fibromata or, possibly, as juvenile forms of these tumors, we are convinced that the particular traits of these five cases justify placing them in a separate category, along with some of the cases reported in the literature as chondromyxoid fibromata. The significant traits of these tumors are: (1) occurrence in childhood (ten years old or younger); (2) symptomatology marked by pronounced pain and swelling; (3) marked periosteal reaction on roentgenograms; (4) rapid progression with only a few weeks to two to three months between onset of symptoms and treatment; (5) absolute predominance of the myxoid tissue, with only a few rare chondroid cells; (6) positive reaction for metachromasia; (7) invariable recurrence after simple curettage; and (8) complete recovery after resection.

Although it is our impression that a few of the cases reported in the literature as chondromyxoid fibromata correspond exactly to our five cases, this impression cannot be verified with complete certainty. Unfortunately, in most reports on chondromyxoid fibromata the clinical picture, the roentgenographic appearance, and the histological findings are each reported separately, so that it is either difficult, or impossible, for the reader to ascertain which roentgenographic appearance goes with which clinical report. After reviewing the literature we doubt that a slowly progressing tumor of distinctly chondroid and cartilaginous nature goes together with an intense and extensive periosteal reaction adjacent to the lesion if it occurs in patients ten years old or younger. On the other hand, similar tumors should have the myxomatous component much reduced in patients about forty years of age and be much less aggressive.

The soft, gelatinous appearance, the absolute predominance of myxoid tissue, the positive metachromatic reaction with toluidine blue in the intercellular substance, all indicate that these tumors are myxomata. The fact that chondroid elements are present, although inconsistently and only in limited areas, can be attributed to the origin of these tumors from skeletal mesenchymal tissue which possibly has some slight tendency to differentiate into cartilage and bone. From the practical, therapeutic point of view, the classification of these tumors into a special group appears even more justified. The surgeon must know that there occurs in the metaphyses of long bones, most frequently in the tibia and the femur, a rather rare tumor which has a characteristic roentgenographic appearance; which occurs in children up to ten years of age; which runs a rapid, often explosive course; and which recurs if treated with simple curettage. The surgeon should, therefore, not underestimate the aggressiveness of this tumor and should, from the beginning, treat it in a radical manner.

SUMMARY

A rare neoplasm of bone which shows great resemblance to that referred to in the literature as chondromyxoid fibroma is described. Two new cases are reported and three similar ones previously published are mentioned in brief.

The characteristics of the neoplasms that differentiate them from chondromyxoid fibromata are: onset in childhood, pronounced symptomatology, rather

rapid course, predominance of myxoid tissue, metachromasia in the ground substance, and invariable recurrence after simple curettage. In view of these traits it is proposed that this tumor be called *myxoma of bone*. Surgeons are advised to treat these tumors by radical local resection.

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Pectoralis Major Muscle

Function of Sternal Portion and Mechanism of Rupture of Normal Muscle: Case Reports

BY LEONARD MARMOR, M.D., CHARLES O. BECHTOL, M.D., AND CAMERON B. HALL, M.D., LOS ANGELES, CALIFORNIA

From the Department of Surgery, Division of Orthopaedics, University of California Medical Center, Los Angeles

The function of the pectoralis major muscle is of interest because, on occasion, this muscle is congenitally absent and increasingly it is being used as a muscle transplant. What loss of shoulder motion results from absence or transplantation of the pectoralis major muscle? In this article, we shall attempt to answer this question and also to demonstrate the mechanism of rupture of a normal muscle.

Much has been written concerning ruptures of various muscles in man, but, to our knowledge, there has been no mention of rupture of the pectoralis major muscle. Rupture of this muscle is rare. Attrition of its tendon—the result of the tendon's rubbing over a prominence of bone—does not normally occur. Hence,

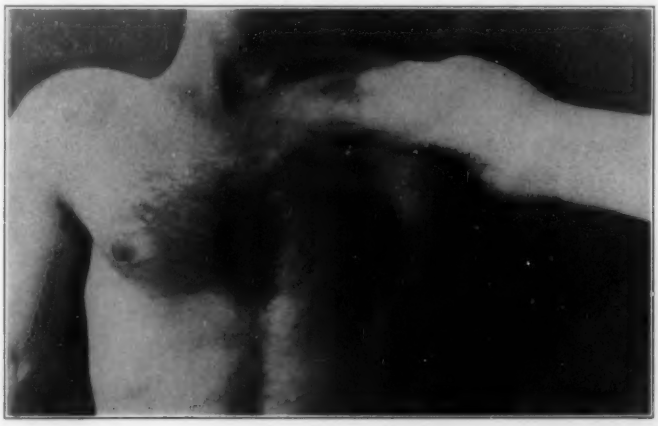

FIG. 1

Patient R. W., with congenital absence of the costal portion of the pectoralis major muscle.

the degeneration of the tendon that almost invariably precedes tendon rupture does not usually occur here, and rupture of the tendon of the pectoralis major muscle may be presumed to be caused by trauma to a normal tendon. The majority of subcutaneous tendon ruptures reported in the literature are associated with pre-existing degeneration of the tendon or to some other pathological condition that makes the tendon susceptible to rupture.

To our knowledge, the mechanism of rupture of a normal pectoralis major tendon has not been discussed in the literature. We have observed two such ruptures in well trained athletes and have arrived at some conclusions as to the mechanism of these ruptures.

ROLE OF THE PECTORALIS MAJOR MUSCLE IN SHOULDER FUNCTION

After traumatic rupture of the pectoralis major muscle, pain tends to obscure

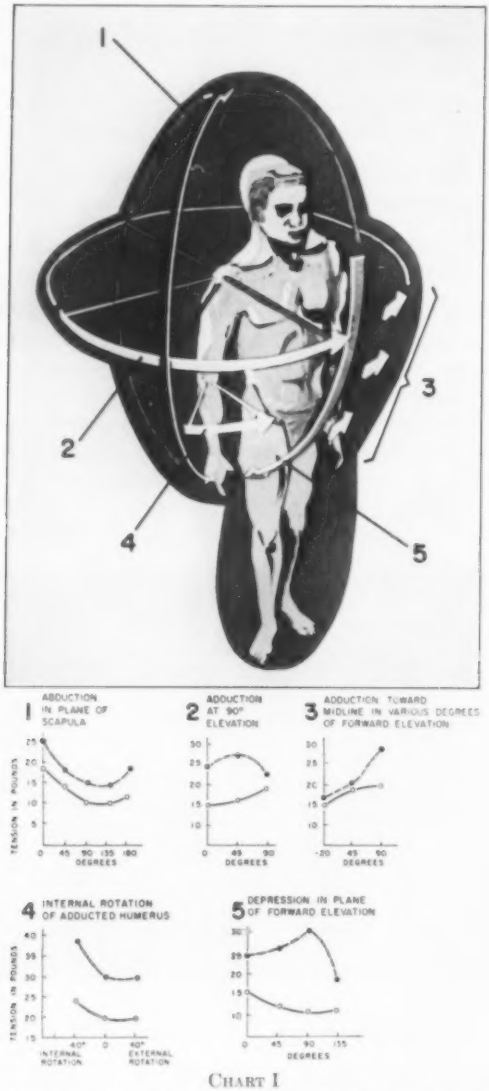

CHART I

Graphs 1 through 5: The ordinate is the tension in pounds developed by isometric contraction of the shoulder muscles in the various positions indicated on the abscissa when the subject attempted to abduct, adduct, or internally rotate the arm, as indicated.

the picture. It is not possible to determine if the rupture is partial or complete, and an accurate determination of the loss of function associated with lack of this muscle is not possible. An opportunity to study the role of the sternal portion of the pectoralis major muscle was afforded by patient R. W. because of unilateral congenital absence of this portion of the muscle (Fig. 1). This anomaly was an incidental finding during a physical examination undertaken because of a disability of one of the lower extremities. As nearly as could be determined by examination, all the patient's other shoulder muscles were normal. There was no significant loss of strength of those motions of the shoulder that did not require

function of the sternal portion of the pectoralis major muscle, but some loss of strength was found in the other motions.

Testing Technique

The strength of this patient's shoulder muscles on both sides was measured with an accurately calibrated cable tension tester. Quantitative determinations were made of the force developed by isometric muscle contraction during abduction, internal rotation, and adduction, with the shoulders in various positions. The tests were carried out with the patient standing adequately braced against a wall or table to prevent loss of balance or sliding of the feet on the floor during the muscular effort. In each test the arm was carefully placed in the appropriate position, and care was taken to test both arms in comparable positions. A loop of piano felt was placed around the patient's wrist to act as a pad and prevent discomfort from pressure from the cable tension tester as it was held against the felt as a counterforce to the patient's effort. The patient was instructed to exert maximum effort in performing the motion under test. This muscular effort was resisted by the examiner, who held the tester. In this way the subject exerted a maximum isometric contraction, and the maximum force that developed was recorded by a maximum pointer on the tester at the instant when the muscular effort of the subject was overcome by the resistance offered by the examiner holding the tester. The maximum isometric tensions developed by the patient with the shoulder in these different positions were plotted as points on Graphs 1 through 5 in Chart I.

Results

The right extremity was dominant in this patient. The heavier interrupted line in all the graphs represents the results of tests of the dominant arm, which, as could be anticipated, was slightly stronger throughout the range of each motion tested.

In abduction in the plane of the scapula (Graph 1, Chart I), there was no significant difference in the strength of the right and left arms. The dominant arm was slightly stronger, but the two curves are of the same shape and close together, indicating that in this movement there is no loss of strength related to lack of the sternal portion of the pectoralis major muscle. In horizontal adduction at 90 degrees of elevation (Graph 2, Chart I), the most striking reduction in strength occurred between 90 degrees of lateral abduction and 90 degrees of flexion. In some positions the reduction amounted to a loss of almost 50 per cent. In adduction toward the mid-line in various degrees of forward elevation (Graph 3, Chart I) there was also a significant but less marked loss of strength in the arm that lacked the sternal portion of the pectoralis major muscle. In internal rotation of the adducted humerus (arm at the side of the chest and elbow flexed at 90 degrees) (Graph 4, Chart I), absence of the sternal portion of the pectoralis major muscle caused significant diminution of strength. In depression in the plane of forward elevation, from 135 degrees of forward elevation (Graph 5, Chart I), there was also significant but less marked loss of strength in the arm without the sternal portion of the pectoralis major muscle.

Comment

It is evident from these findings that surgical repair of a ruptured pectoralis major muscle is worthwhile in an athlete, since without this muscle there is significant loss of strength in most motions that internally rotate the humerus or bring it toward the mid-line. Strength in these motions is quite important in

FIG. 2-A

Patient C. W., with rupture of the left pectoralis major muscle. Note the loss of the costal bulge and the ecchymosis of the arm.

FIG. 2-B

Roentgenogram of chest, showing absence of the shadow of the pectoralis major muscle. We present this as a pathognomonic finding in this condition.

most athletic endeavors. However, the loss of strength is not complete, and in a sedentary person, particularly if there are other complications, it would be entirely acceptable to treat the ruptured pectoralis major muscle by allowing it to heal spontaneously without surgical repair. The patient R. W., with congenital absence of the sternal portion of this muscle, stated that he had never had any particular difficulty with the arm that lacked this muscle except during strenuous athletic activities, when he noted some weakness during adduction and internal rotation of the shoulder.

MECHANISM OF RUPTURE OF NORMAL TENDONS IN WELL TRAINED ATHLETES

Two athletes in good physical condition who had sustained ruptures of the pectoralis major tendon during athletic endeavor were interviewed and examined with particular reference to the mechanism of injury.

CASE 1. C. W., a white male college student, twenty-five years old, was admitted to the

FIG. 2-C

Postoperative roentgenogram, revealing the presence of the shadow cast by the pectoralis major muscle after repair.

FIG. 2-D

Postoperative photograph showing the patient with repair of the ruptured pectoralis major muscle.

University of California Medical Center, Los Angeles, with the chief complaint of pain and swelling of the left shoulder and breast. Several days prior to admission, as he had attempted to lift a 250-pound bar bell directly upward while he lay supine on a table, the weights shifted on the bar to the left. He exerted a sudden maximum effort to prevent the weights from falling and felt a tearing pain in his left shoulder. Examination of the patient revealed an extremely well developed young man with a large area of ecchymosis involving the medial aspect of the left arm, axilla, and pectoral region (Fig. 2-A). A mass was palpable over the breast, and there was local tenderness over the belly of the pectoralis major muscle with weakness of shoulder function. The complete blood count, urinalysis, and serological tests were within normal limits. Roentgenograms revealed absence of the shadow of the pectoralis major muscle on the left as compared with the right (Fig. 2-B). Absence of this shadow is a reliable sign of rupture of the pectoralis major muscle and is an aid in diagnosis, as illustrated in Figure 2-C, which shows the roentgenographic appearance of the pectoralis major muscle after surgical repair. At operation, a tear of the sternal portion of the pectoralis major muscle was found, with the clavicular portion intact. The tendon, which had avulsed from the bicipital groove, was repaired with No. 1 braided silk sutures passed through drill holes in the humerus. The postoperative course was uneventful, and, two months after repair, the patient had full range of shoulder motion and could lift or press 250 pounds of weight (Fig. 2-D).

Case 2. A. C., a white male, twenty-four years old, injured his left shoulder region three years previously when he was training for a wrestling bout. He had been working-out for about two hours with different partners and was becoming quite fatigued. Upon applying a headlock to his opponent, the patient found that the muscles of his arm were too tired to turn his opponent's head preparatory to throwing him to the mat and, therefore, he threw the weight of his body behind this effort. Pain in the left pectoral region was immediate, and there was an audible tearing sound "like a piece of heavy canvas". During the next few minutes there was considerable swelling and increasing pain in this area. The injury was treated with heat and rest over the next few days, and extensive ecchymosis developed; four weeks later the swelling and ecchymosis had disappeared. There was no surgical treatment. Six weeks after injury there was considerable atrophy of the left pectoralis major muscle and weakness in the motions of this shoulder. There was a definite physical defect in the lower portion of the pectoralis major muscle adjacent to the deltopectoral groove. The patient stated that he ordinarily kept in condition for wrestling by weight-lifting, and at this time he began to condition the muscles of his left shoulder by carrying out an ordinary weight-lifting program. At first he was very weak in any motions requiring forward elevation of the arm. However, over a period of about six months the strength of the arm gradually returned, although a visible defect in the muscle remained. At the time of examination he stated that he felt the strength of his two arms was about equal. He cited the example that he could do all of the various lifts with dumbbells of equal weight on the right and left side. He was right-handed.

On examination there was a visible and palpable defect in the lower fibers of the pectoralis major muscle adjacent to the deltopectoral interval. The patient was exceedingly well developed and had an excellent record as a wrestler, both before and after the injury. With quite heavy weights he was able to perform the various standard "lifts" that activated the muscles around the shoulder, and demonstrated equal power on both sides. The diagnosis was a partial tear of the pectoralis major muscle at its musculotendinous junction involving the lower portion only.

The significant points in the history relating to this muscle tear are that first, his muscles were very well developed, and second, that when the tear occurred he had become fatigued and used improper body mechanics to carry out the wrestling hold; that is, he set the muscle at its maximum contraction and then suddenly applied force by throwing the weight of his body.

DISCUSSION

Ralston and his associates demonstrated the relationship between the load and the maximum velocity of contraction in human muscles that contained cineplasty tunnels. The load-velocity curves were determined on the sternal portion of the pectoralis major muscle. The data that they collected showed beyond doubt that force and maximum velocity for a wide variety of muscles follow the formula $(P + a)(v + b) = \text{constant}$ where P represents load, v represents velocity, b represents a constant having dimensions of velocity, and a represents the shortening heat per unit shortening and has the dimensions of force. With this formula it can be shown that the maximum force that a muscle can develop is a certain percentage of its isometric tension. From a practical standpoint it can be said that a muscle develops its maximum power when lifting a load equal to about one-quarter to two-fifths of the maximum isometric tension that it can develop. Conversely, it can be said that a muscle can hold about four times as much weight as it can lift. As nearly as could be ascertained from the descriptions of the injuries reported here, the ruptures occurred after the subjects had become fatigued and when they attempted maximum effort by "setting" the muscle and throwing the weight of the body into the effort. In other words, the subject maneuvered his body so that the muscle that subsequently ruptured was placed in a position of merely holding resistance, and the actual force was applied by movement of the entire body. Under such conditions, according to Ralston and his associates, the muscle could produce about four times the tension it would ordinarily produce if the athletic activity were carried out with proper coordination. In the first case, at operation it was found that the rupture occurred at the insertion of the tendon. This is in accordance with the findings of McMaster, who showed in experiments with animals that the normal tendon does not rupture unless severely injured. Under heavy loads the tendon insertion or musculo-

tendinous junction would rupture rather than the tendon itself This fact is borne out clinically by Case 1 and by the findings of Steindler, who stated that rupture of the musculotendinous junction is more common in younger persons than in older persons whose tendons have degenerative changes.

CONCLUSIONS

1. The pectoralis major muscle is not necessary for normal shoulder function but is required in the performance of athletics or other strenuous activity.

2. Normal tendons do not rupture except at the musculotendinous junction or the tendon insertion.

3. A muscle can hold about four times as much as it can lift. Ruptures of muscles in healthy athletes are due to the application of excessive weight when the muscle is holding at its maximum power.

4. A roentgenogram of the chest will reveal the absence of the shadow of the pectoralis major muscle if rupture has occurred, and this can be an aid in diagnosis.

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An Unusual Case of Metaphyseal Growth Disturbances

BY COLONEL JOHN J. BRENNAN, *Medical Corps, United States Army,*
AND MAJOR CHRISTOPHER A. GUARINO, *Medical Corps, United States Army Reserve*

From The Orthopaedic Service, William Beaumont General Hospital, El Paso, Texas

Only a few instances of growth disturbance limited to the metaphysis have been recorded in the literature. In 1931 Pyle reported on a four-year-old boy with unusual bone growth, and Bakwin and Krida reported on this same boy when he was eleven years old, together with his sister, who was four years old, who had similar abnormalities. These authors termed the disturbance in these children *familial metaphyseal dysplasia*. Similar cases were described by Hermel, Gershon-Cohen, and Jones and by Sear.

Jansen, in 1934, reported a case that he termed *metaphyseal dysostosis*, and Lenk recorded a similar case in 1956 as *hereditary metaphyseal dysostosis*. These two cases were reviewed by Fairbank, who considered them similar.

Blount[1], in 1937, reported epiphyseal disturbance in growth of the upper part of the tibia termed *tibia vara* or *osteochondrosis deformans tibiae*.

The case to be reported here does not resemble any of those previously reported.

A two-year-old boy was admitted to William Beaumont General Hospital on April 27, 1957, because of marked bowing of his legs that had been present since birth. The parents felt the bow-leg deformities were becoming progressively worse. The child had suffered no trauma to the lower extremities recently or in the past. He had complained of some tenderness about both legs on one occasion one week prior to admission but this had not seriously hindered his activities.

The boy's birth had been normal. His development and intellect were judged to be normal by the parents. He had walked at thirteen months of age, and nothing unusual had been noted about his early walking. His activities and play were normal. There was no history of serious illness or fever. The child had received a vitamin supplement to his diet since birth.

The family history revealed that the patient's father had had bow-leg deformities as a child, and his knees had straightened normally without treatment. The patient's older brother had bow-leg deformities of mild degree that straightened as he grew. His maternal uncle also had bow-leg deformities, and three of this uncle's children in their youth had bow-leg deformities that were corrected successfully by surgical procedures. The medical records of these relatives could not be obtained.

The physical examination revealed a healthy-appearing child who was alert and active. He showed marked bowing of both lower extremities, with slight visible enlargement of the bones at the knee. With the medial malleoli held together, the distance between the medial femoral condyles of the extended knees was ten centimeters. There was considerable internal rotation of both tibiae. The ligaments of the knees were stable.

The complete blood count, urinalysis, and serologic tests were within normal limits. The blood calcium was 10.5, the inorganic phosphorus was 5.04, and the non-protein nitrogen was 29.9 milligrams per 100 milliliters; the total protein was 6.58, the albumin was 4.99, and the globulin was 1.59 grams per 100 milliliters; the albumin-globulin ratio was 3:7; the protein-bound iodine was 6.8 micrograms; and the alkaline phosphatase was 7 King-Armstrong units.

Roentgenograms (Fig. 1) of both lower extremities revealed marked varus deformities of the knees, due primarily to changes in the proximal tibial metaphyses and to a lesser extent to deformities of the distal femoral metaphyses. Both tibial metaphyses were markedly irregular, particularly in their medial portions. A vertical line of diminished density extended downward from both epiphyseal plates. Taking origin from near the middle of each epiphyseal plate, these lines of diminished density extended through the medial cortex of the tibia close to the beginning of the outward flare of the metaphyseal region. These lines resembled the nearby epiphyseal plates. They gave

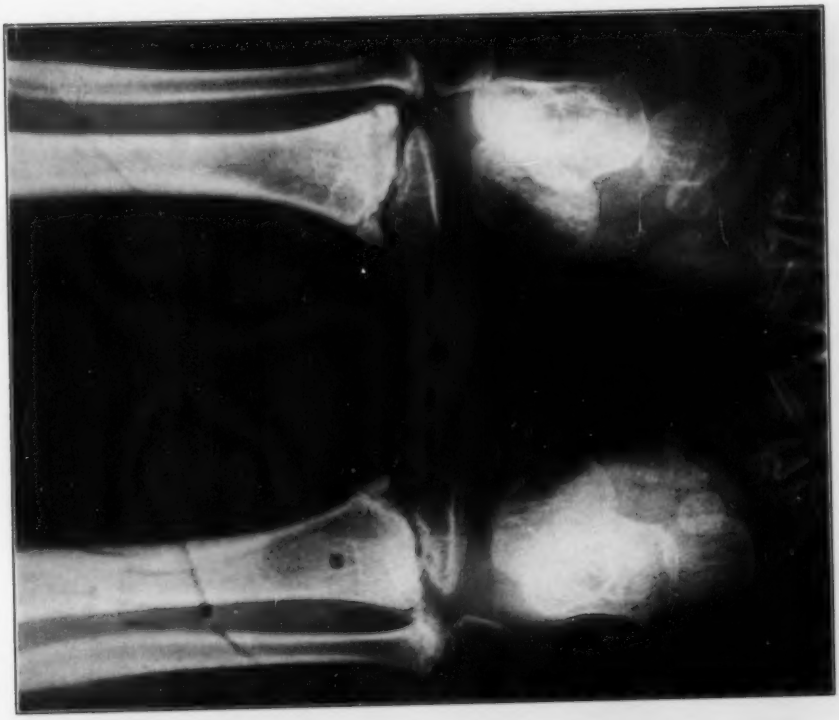

Fig. 2

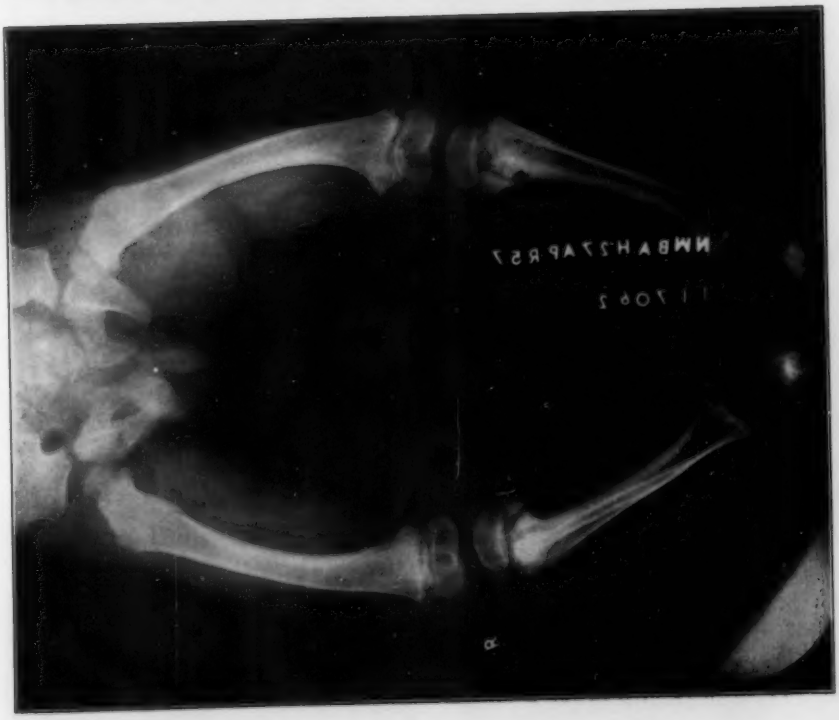

Fig. 1

Fig. 1: Anteroposterior roentgenogram of the lower extremities, showing genu varum and metaphyseal defects.
Fig. 2: Anteroposterior roentgenogram of both ankles, showing smaller metaphyseal defects of the distal ends of the tibiae.

FIG. 3

FIG. 4

Fig. 3: July 8, 1957, anteroposterior roentgenogram of the lower extremities, showing healed osteotomies of both tibiae and obliteration of the upper tibial metaphyseal defects.

Fig. 4: Anteroposterior roentgenogram made in January 1960, showing further spontaneous correction of the varus deformities and complete obliteration of the metaphyseal defects.

each proximal tibial epiphyseal line a Y-shaped contour and, in addition, seemed to outline an island of bone in each proximal medial tibial epiphysis. The architecture of the bone in the tibial metaphyseal regions appeared sclerotic and irregular.

The metaphyses of the distal ends of both the femora, distal ends of the tibiae, and distal ends of both fibulae also showed slight irregularity (Fig. 2). Roentgenograms of the rest of the skeleton, including the hips, spine, skull, and upper extremities, were normal. The metaphyseal abnormalities were limited to the lower extremities, sparing only the proximal metaphyses of the femora and fibulae.

Pediatric, roentgenologic, and orthopaedic consultants could arrive at no definite diagnosis. It was presumed that this condition was a variant of metaphyseal dysplasia or metaphyseal dysostosis (Jansen)[5].

Because of the marked bowing of the legs, bilateral corrective osteotomy of the upper ends of both tibiae was performed on May 7, 1957. The patient's postoperative course was uneventful. The lower extremities were immobilized in a bilateral toe-to-groin hip spica until the osteotomies healed. The cast was removed, and bilateral toe-to-groin braces were applied on July 8, 1957. Lateral pressure pads at the level of the knees were added to the braces to provide a corrective force. The braces were used for four months.

Roentgenograms made on July 8, 1957, when the cast was removed, showed that the osteotomy sites of both tibiae were well healed. In addition, the abnormal lines of diminished density in the proximal tibial metaphyses had also disappeared, with complete obliteration of the lines and incorporation of the apparent separate fragment of bone into the metaphysis (Fig. 3). The irregularities in the distal metaphyseal areas of the femora and tibiae persisted until July 19, 1957, when they were found on roentgenograms to be nearly obliterated. Repeat roentgenograms on January 4, 1960, showed no evidence of recurrence of the metaphyseal abnormalities or the bow-leg deformities, although some slight metaphyseal irregularity still exists in these metaphyses (Fig. 4).

Good correction of the varus deformities was obtained by the osteotomies, but slight internal tibial torsion of the left tibia persisted. This responded well to use of a Denis Browne night splint, which was worn from September 1957 to January 1958, when derotation was complete. The child then continued to be very active, and the varus deformity of the lower extremities had not recurred at the time of writing.

COMMENT

An unusual abnormality of bone development of the lower extremities associated with severe bow-leg deformities in a two-year-old boy has been presented. The changes were confined to the metaphyseal regions of the long bones of the lower extremities not including the proximal parts of the femora or fibulae. The most marked changes were located in the proximal tibial metaphyses. Here, nearly vertical lines of decreased density, resembling extensions or branches of the epiphyseal plates, gave each epiphyseal line a Y-shaped contour and seemed to isolate the medial portion of each metaphysis as a separate bone fragment. Osteotomies through the proximal part of the tibiae just distal to the abnormal regions corrected the varus deformities and resulted in spontaneous disappearance of the abnormality of the epiphyseal plates. The abnormality described here is believed to represent a variation of metaphyseal dysplasia (Jansen). Like most metaphyseal defects the abnormalities in this case seemed to disappear spontaneously with growth.

NOTE: The authors wish to acknowledge gratefully the valuable assistance furnished in both the treatment and the attempt to classify this condition by Dr. Louis W. Breck and Dr. Walter P. Blount[2].

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DISCUSSION

Prognosis of Fractures of the Acetabulum

(Continued from page 59)

the more vigorous were the remedial exercises performed during the convalescent stage, the better the end result. Motion was invariably maintained in the planes of activity.

We all agree that interruption of the blood supply to the femoral head is probably the prime cause for the development of avascular necrosis. However, I would like to ask the essayists if they believe the severe force and counterforces which are necessary to produce dislocation of the hip and fracture of the acetabulum could cause molecular changes in the organic and inorganic substance of the femoral head sufficient to produce death of bone?

Dr. Carl E. Badgley, Ann Arbor, Michigan: Surgery in the United States owes a great debt of gratitude to the Massachusetts General Hospital Staff for their traditional devotion to honest end-result studies initiated so many years ago by Codman. This paper is in keeping with such an honest appraisal. Purposefully, the authors have eliminated from their study all cases of acetabular fracture that were not initially treated by them. The end results reported are, therefore, the product of the Fracture Service of the Massachusetts General Hospital.

There is so much meat presented that one can discuss only a few of the important features.

The classification of fractures of the acetabulum is brief and descriptive: linear; inner wall; posterior; and superior and bursting.

I think they would agree to add to the last two groups the phrase "with or without displacement of the head", for dislocation may be the major cause for a poor prognosis.

I agree entirely with the conclusions reached by the authors in this study. The indications for surgical intervention promptly, when necessary, are given, as well as emphasis on the successful results to be obtained by conservative therapy otherwise, for which there is ample proof. The unnecessary and arduous attempt at surgical repair of the inner-wall fragments, which respond so well to simple traction methods, has been stressed by the authors.

The immediate need for a successful reduction of the dislocated head of the femur has been stressed by the authors. Their rule is, doubtlessly, appreciated by everyone. However, in my own clinical experience with fracture-dislocations of the hip that have had their initial treatment elsewhere, failure of recognition of displacement of the head of the femur has been a common error in a number of cases.

Our group has developed a technique of lateral roentgenography of the pelvis with the affected hip down, applicable in fresh and late fractures, which demonstrates clearly the relationship of the femoral head to the acetabulum. The marked displacement that may be seen here is common in all posterior acetabular fracture-dislocations. Also, some of the supposed inner-wall fractures have a posterior fracture-dislocation, as well.

Our roentgenograms illustrate the value of the lateral view of the pelvis in the appreciation of the true displacement. Central dislocation of the hip is somewhat different.

Roentgenograms made in 1951 of a man, twenty-three years old, showed disruption of the acetabulum and intrapelvic protrusion, with many severe fractures; he also had extensive brain damage. The superior dome of the acetabulum was fragmented. Reduction was impossible by traction. Roentgenograms made in 1957 demonstrated further displacement of the central fracture-dislocation, yet the patient was able to walk unaided and without clinical pain.

Aseptic necrosis can occur late in inner-wall fractures, as happened in a patient who sustained intrapelvic displacement in 1945 in Korea, but whose serious symptoms did not develop until 1959.

Early operation is certainly advised when the sciatic nerve is stretched over the bone fragment and the bone fragment has definitely infringed on the nerve.

I congratulate the authors for an excellent end-result study. This is, to date, the most authoritative report on acetabular injuries.

Hip-Shelf Operation in Adults

BY DAVID M. BOSWORTH, M.D., J. WILLIAM FIELDING, M.D., TADAO ISHIZUKA, M.D., AND RIDVAN EGE, M.D., NEW YORK, N.Y.

From the Orthopaedic Service, New York Polyclinic Medical School and Hospital, New York

The shelf operation for the stabilization of the hip in an adult is not a new procedure in orthopaedic surgery. Therefore, it is not the purpose of this paper merely to report our results with this procedure but rather to describe certain modifications of the original concepts regarding the indications for this operation and some modifications in the operative technique, with particular reference to the size and length of the graft, the proper position of the shelf, and the manner of implantation and fixation of the shelf.

Over a period of twenty-four years we performed hip-shelf procedures on only thirty-three adults. During this same period many more adults with hip disease were treated by either fusion or reconstruction of the hip or by the insertion of a prosthesis. In all of the patients included in the present series the original examination and the decision to perform a shelf operation were made by the senior author in association with one or more of the other authors. The review of the records and roentgenograms and the analysis of the data on which this report is based were carried out by all the authors. We do not wish either to encourage or to condemn the use of this procedure for any given hip disease. We wish only to record how we have treated these patients; to describe our new techniques used since 1946; and to report what has happened to the patients on whom we have performed these procedures.

STATISTICS

Of the thirty-three patients included in this series, thirteen had bilateral procedures, making a total of forty-six operations. Three of the patients with bilateral procedures had both hips operated on at the same time.

In this study of consecutive cases, the patients had follow-ups of not less than three years and not more than twenty-five years; the average follow-up was nine years.

At operation, the oldest patient was fifty-four years of age and the youngest, eighteen; the average age was thirty-five years.

Eighteen right and twenty-eight left hips were operated on. All patients were white; thirty were female and three were male.

The time recorded for the performance of the procedure ranged from ten minutes for a patient with unilateral hip disease to sixty-five minutes for a patient with bilateral involvement; the average time was forty minutes. The time was essentially the same for both the old and the new type of procedure, both of which are to be described herein.

COMPLICATIONS

There were no deaths in this series and only one wound infection. This wound spontaneously drained serous fluid ten days after operation from which hemolytic *Staphylococcus aureus* was cultured fourteen days after operation. For the first three days thereafter the patient was given penicillin and aureomycin; after the

bacterial sensitivities were determined, erythromycin was used. The staphylococcus rapidly became resistant to all antibiotics. Therefore, four weeks after operation, two milligrams per kilogram of body weight per day of iproniazid was begun and antibiotics were stopped. The wound, supported with strapping and bandages over simple dressings, gradually healed; three months after operation it finally closed. Iproniazid was continued for an additional three months. Neither roentgenographic nor clinical examination revealed any sequelae of this infectious process. The shelf remained intact, became incorporated, and maintained the stability of the hip.

Early in this series, in 1943, a pulmonary embolus developed after operation, in association with phlebitis of one leg in a patient who was immobilized in a cast. Pneumonia developed after operation in another patient who was treated by the new procedure, without immobilization. Both patients recovered; there were no demonstrable sequelae.

There were no other operative complications, nor were there any operative accidents.

HOSPITALIZATION AND TIME TO WEIGHT-BEARING

Before 1946, fifteen patients (twenty-two hips) were immobilized in plaster hip spicas after operation and kept in the hospital for six weeks. In 1946, we instituted a change in surgical technique that provided greater stability of the shelf and eliminated the need for plaster fixation. The indications for the shelf operation and the result in the fifteen patients operated on before 1946 were essentially the same as those in the patients treated after 1946 with the exception, of course, of the hips in the first series in which the grafts failed to remain in place. Among the twenty-two hips treated by the old technique, the outer end of the graft displaced to a variable extent in seven and the inner end displaced in six. These complications, combined with the discomfort caused by the spica cast and the prolonged hospitalization, both of which were hard for patients to accept, stimulated the development of the present technique. None of the shelves implanted by this method (after 1946) have moved from their original positions.

After the development of the new technique, the duration of the patients' hospital stay was much less; it varied, in uncomplicated cases, from five to twelve days, and the patients were discharged non-weight-bearing on crutches. The patient who had pneumonia remained in the hospital for three months.

Partial weight-bearing with crutches was permitted from ten days to six weeks after operation; the average time was the fourth postoperative week. The time for weight-bearing depended on the stability of the femoral head (dislocation, subluxation, or coxa magna) prior to operation.

Walking with a cane was allowed from one to three weeks after weight-bearing on crutches was begun. The cane was discarded after it had been used for a minimum of one and a half months to a maximum of one year. However, one patient on whom a bilateral procedure was performed continued to use a cane for two years after operation; it was difficult to convince her that her hips, which had been unstable all her life, would now support her. The average period before removal of all support was five months.

INDICATIONS, DIAGNOSIS, AND COMPARATIVE RESULTS

The indication for the shelf procedure in this series was instability of the hip, or pain, or a combination of these.

As the term is used here, stability of the hip refers to both objective and subjective stability. Objective stability is assumed to be present if the relation-

FIG. 1-A

February 5, 1949

FIG. 1-B

February 4, 1960

Figs. 1-A and 1-B: A female clerk, with congenital dislocation of both hips, was twenty-nine years old when first seen by us. She had never received any treatment for her hips. During her adult life walking had gradually become painful and for the last five years before admission pain had become severe. Physical examination revealed a severe bilateral lurch, marked restriction of motion of both hips, and severe telescoping of the left hip.

A shelf operation was performed on the left hip on April 4, 1949, and on the right hip on May 2 of the same year. The patient was hospitalized for forty days, first in bed and then in a wheelchair. Thereafter, she used crutches for ninety days and then no support at all. After discarding crutches she returned to work and at that time was able to travel by public conveyance.

Examination on February 4, 1960, showed that the patient had retained the same ranges of hip motion she had before operation. The Trendelenburg sign was still positive on both sides, but she had no pain and was working regularly. Although a limp was still noticeable, it was markedly reduced. There was no longer any telescoping of the left hip.

ship between the femoral head and pelvis remains unchanged during stress of weight-bearing and during active or passive movement of the hip. Objective stability is likewise assumed to be established if imminent dislocation or subluxation or potential subluxation is prevented. Potential subluxation is that type of subluxation that occurs over the years in the presence of an inadequate acetabulum, coxa magna, or similar disorder in which the components of the hip joint are not in proper alignment.

Subjective stability refers to the sensation of adequate support or security that the patient experiences when there is a bone buttress over the top of the femoral head sufficient to prevent overt or minute upward displacement of the femur during weight-bearing.

FIG. 2-A
April 3, 1950

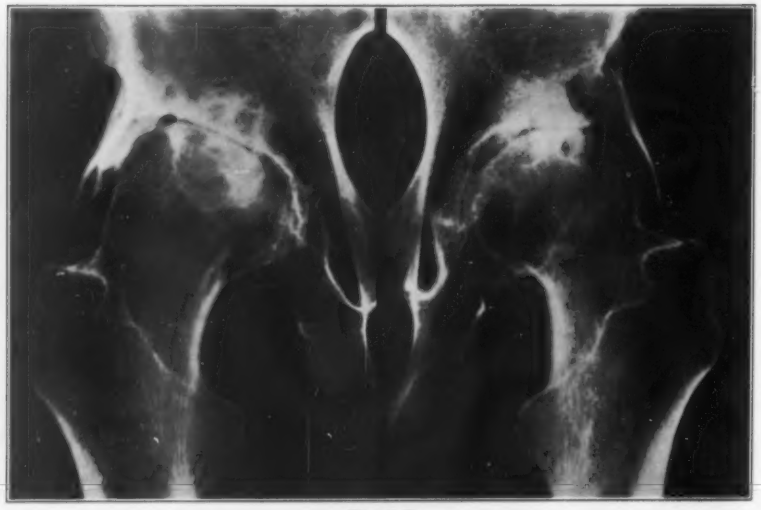

Fig. 2-B
September 28, 1959

Figs. 2-A through 2-D: This patient was first seen when she was thirty-five years old. She had had a congenital dislocation of the left hip; closed reduction had been attempted when she was two and a half years old. For five years prior to admission, fatigue on stress and pain on walking had gradually increased on the right side; during the last seven months, the pain was so severe she had to stop working.

A right hip shelf was implanted on May 24, 1950. The patient's legs were bandaged together at night for three weeks after operation, at which time she started weight-bearing. She used crutches for three months and then a cane for two months. Since then the right hip has "not bothered" her and she has been able to keep house.

In 1955 pain developed in the left hip and gradually became severe. On October 1, 1956, a shelf was implanted over the left hip, which had an inadequate socket, in an attempt to arrest the sclerosing osteo-arthritic changes. At first the patient had relief from pain, but two years later pain recurred and cystic changes were noted in the femoral head. On October 26, 1959, the head of the left femur was resected and a prosthesis was inserted.

The patient was last examined on July 13, 1960. At that time the left hip had flexion to 85 degrees and extension to 185 degrees, with 60 per cent of normal motion in the other directions. She was weight-bearing without support in her home; outside, however, she continued to use crutches. She was free of pain, but had a moderate bilateral limp on unsupported weight-bearing. Delay of full weight-bearing was encouraged to allow for reossification beneath the prosthesis.

FIG. 2-C
July 13, 1960

FIG. 2-D
July 13, 1960

In this study stability was said to be established when objective and subjective stability, as defined here, was found at follow-up examination. It should be noted that stability of the hip, in this sense, does not take into consideration the hip musculature. Hence, in this series we may say that a subluxating hip with para-

FIG. 3-A
Left: December 26, 1934

FIG. 3-B
Left: June 24, 1960

lyzed hip muscles is stabilized by a shelf procedure if a shelf is formed adequate to maintain the femoral head in a fixed position, even though the patient has a positive Trendelenburg test and walks with a limp.

In this series there were several hips on which shelf operations were performed in the presence of only moderate instability or moderate pain. In these instances the operation was a prophylactic measure to prevent the virtually inevitable progressive deformity that is associated with disproportionate size, incongruity, or abnormal spatial relationships of the components of the hip joint.

The shelf operation was performed on twenty-eight hips with congenital dislocation, on fifteen hips with congenital subluxation (dysplasia of the acetabulum and coxa magna), and on one hip with paralytic dislocation caused by anterior poliomyelitis. In many instances there were early arthritic changes consequent to an inadequate socket and a large head. There were two patients with coxa magna and advanced degenerative arthritis on whom shelf operations, instead of hip fusions, were performed. In these two patients pain in the hip was the primary indication for treatment.

The patients with congenital dislocation had received extensive treatment prior to the shelf operation. All except one had had unsuccessful closed or open reductions. At the time that the shelf procedures were performed two of the patients with congenital dislocations were totally disabled by pain in the buttock and hip and by easy fatigability. Using crutches they were only able to get from a bed to a chair or to the bathroom. They were unable to do housework or walk any distance, even with crutches. All patients with congenital dislocations had had to use a cane or crutches before the shelf operation because of marked instability or pain brought on by weight-bearing for variable lengths of time. Similarly, all these patients had a positive Trendelenburg test, normal or excessive passive motion of the hip, obvious telescoping and marked impairment of abduction and extension of the hip, as well as some loss of active movement in the other directions. At follow-up the Trendelenburg test was still positive but telescoping had been eliminated. It was our impression that the strength of the hip muscula-

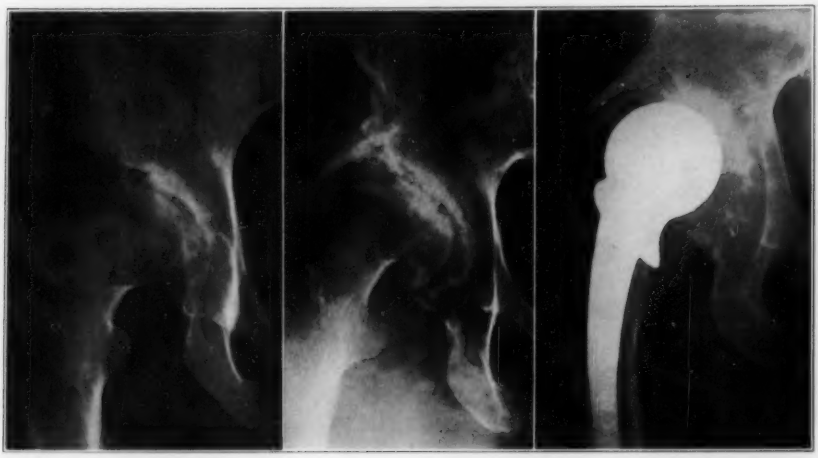

FIG. 3-C
Right: September 11, 1935

FIG. 3-D
Right: September 17, 1959

FIG. 3-E
Right: June 24, 1960

Figs. 3-A through 3-E: A housewife, who was first seen in 1935 when she was twenty-nine years old, had poliomyelitis in infancy and her left hip had dislocated. An open reduction had been performed after unsuccessful closed reduction. When the patient was examined in 1935 the femoral head was absent, leaving only a stump of the neck, and the left leg was three and a half inches short. In addition, marked instability and telescoping of the left hip were evident. Pain had been increasing gradually during the five years prior to admission (Fig. 3-A).

On August 8, 1935, a left hip shelf was applied. After operation the patient was immobilized in plaster for six weeks and then for two additional weeks she walked non-weight-bearing on crutches. Later, leg-lengthening of one and five-eighths inches was done on the left tibia, and triple arthrodesis was done on the left foot.

At examination on June 24, 1960 (Fig. 3-B), the left hip had remained stabilized by the shelf, despite absence of the femoral head and the short neck. The left hip was asymptomatic and did not telescope. Her right hip, however, was beginning to cause trouble.

A roentgenogram made of the right hip on September 11, 1935 (Fig. 3-C), had shown potential instability and subluxation, but the patient was asymptomatic at that time. Nineteen years later, in 1954, progressive osteo-arthritic changes and pain began to develop in this hip; the patient's ability to walk was severely limited.

A shelf was applied to the right hip on June 23, 1958. For a year thereafter the patient was almost free from pain and her limp improved somewhat. After that, pain in the right hip gradually increased (Fig. 3-D) and on September 22, 1959, the head of the femur was removed and a prosthesis inserted.

At examination on June 24, 1960, nine months after operation (Fig. 3-E), the patient was again walking without any pain. Motion in the right hip was 80 per cent of normal in all directions. The left hip had remained stable, asymptomatic, and unchanged. The patient walked without any support in her home; outdoors she used a cane.

ture and control of the hip were much improved after operation, but the records were not sufficiently detailed to permit an accurate comparison of the muscle power and range of active motion before and after shelf operation. Pain and fatigue were markedly reduced. The patients' sense of support and confidence in the ability of the hip to bear weight were improved.

Obviously, there remained, in all of these hips, major defects in the joint mechanics similar to the defects that persist after all reconstructive procedures on the hip. With longer follow-up there may appear symptoms which will demand further surgical treatment. However, for the duration of this study, three to twenty-five years, none of the twenty-eight hips with congenital dislocation required additional surgery.

All of the patients with congenital subluxation of the hip (coxa magna and dysplasia of the acetabulum) had had much less previous treatment than the patients with dislocation. All had had physical therapy of some sort, periods of non-weight-bearing, local injections, traction, stretching, and other treatment. Three

FIG. 4-A

FIG. 4-B

Fig. 4-A: The external ilium just above the right hip joint. The dotted lines in the upper part of the drawing outline the shelf to be removed. The dotted line below, just above and behind the hip joint, indicates the location of the slot in which the shelf will be placed. The capsule is not opened (see text).

Fig. 4-B: When in place the shelf is directed downward and forward and is held in place by the overlying gluteal muscles and reflected head of the rectus femoris. In this position the shelf is stable and no internal fixation or external immobilization is necessary.

of the fifteen hips with congenital subluxation had had previous surgical treatment but these hips were still weak and painful, even though not unstable. In general, before their shelf procedures the patients with congenital subluxation complained primarily of pain, which was usually continuous and aggravated by activity. All of these patients were considerably disabled for active work that required standing or walking; two had such severe pain that they could do little more than get from a bed to a chair with the aid of crutches. All the patients in this group had some restriction of motion and some muscle weakness caused by pain. All had positive Trendelenburg tests. After their shelf operations there was no change in the range of motion, but pain decreased and muscle strength increased. To clinical examination all these patients were considerably improved after operation, but in two instances further degeneration of the hip necessitated reoperation and insertion of a Thompson prosthesis four and one and one-half years, respectively, after the shelf procedures (Figs. 2-A through 2-D). Although secondary procedures may eventually be necessary for more of these subluxated hips, we believe the situation here may be compared with that of fractures of the femoral neck. As a first step, it seems justifiable to attempt to preserve a viable femoral head with a shelf implanted over it, rather than resort to a prosthesis as the initial procedure.

The two patients with coxa magna and arthritis were also severely disabled by pain prior to their shelf operations, even though their hips were stable. Because both of these patients had severe degenerative arthritis of the lumbosacral spine, the shelf procedure was performed in preference to arthrodesis of the hip.

The patient with paralytic dislocation of the left hip consequent to poliomyelitis in infancy had had unsuccessful closed and open reductions of the hip attempted at another hospital when she was an infant. The left femoral head had apparently absorbed, leaving only a very small stub of the neck. At the age of twenty-eight, the patient was completely disabled. A shelf operation rehabilitated her and her hip has remained stable for twenty-four years (Figs. 3-A and 3-B).

FIG. 5-A

May 9, 1960

FIG. 5-B

May 9, 1960

A nurse with congenital dislocation of the left hip was first seen in 1948, when she was twenty-four years old. She had had two closed reductions in infancy and an open reduction when she was six years old, at which time she was in a plaster cast for nine months. During the year before admission she had noticed, when on duty, a gradual increase of pain in the left hip.

A hip shelf was applied on May 2, 1950. Crutches were used for two months, and a cane for one month. She went back to active duty five months after operation and was still asymptomatic on May 9, 1960. At this time there was excellent stability and no demonstrable loss of motion.

Note, in Fig. 5-A, that the medial end of the shelf lies almost directly above the center of the femoral head, whereas the outer end of the graft is anterior and lateral to the femoral head. There is marked hypertrophy of the shelf.

OPERATIVE PROCEDURES

Fifteen patients (twenty-two hips) were operated on prior to 1946. The procedure used in these hips was as follows: Through a curved Smith-Petersen incision, the external surface of the anterior one-third of the ilium was exposed subperiosteally. The origins of the gluteus medius and minimus muscles were elevated, but the direct and reflected heads of the rectus femoris were left attached. The shelf was cut from the outer table of the ilium, leaving its inferior margin attached along the acetabulum. The shelf was then turned downward and its free edge was held in place by suturing it to the capsule through drill holes along its free margin. Chips of cancellous bone, obtained from between the two tables of the ilium, were placed along the superior surface of the base of the graft to reinforce it. Although every effort was made not to break off the shelf where it remained attached to the ilium, in most instances the graft did crack. Only a few of the grafts were sufficiently flexible to bend down and remain intact. It was impossible to determine from the records and roentgenograms which grafts did or did not crack. In all cases an attempt was made to hold the graft in the desired position. This was done not only by the sutures through the capsule, but also by careful replacement of the gluteus minimus and medius muscles over the graft and by a spica cast with a pressure pad placed below the iliac crest, over the region of the shelf. With these measures, and the additional cancellous grafts implanted along the base of the shelf, all of the shelves became attached to the ilium, but some were at a higher level than originally intended.

In 1946 a new operative procedure was adopted and subsequently used on

FIG. 6-A
April 5, 1948

FIG. 6-B
April 5, 1948

FIG. 6-C
March 21, 1960

FIG. 6-D
March 21, 1960

Figs. 6-A through 6-D: This nurse, a cousin of the patient in Figs. 5-A and 5-B, also had congenital dislocation of the hip and was also seen in 1948, when she was twenty-four years old. During infancy she had had her hip manipulated by a chiropractor on three occasions. When she was six years old, her hip was again manipulated; this time she was in a cast for nine months. Pain began to develop six months prior to admission; it gradually became so severe she could no longer work.

A shelf was implanted on April 29, 1948. Three months later the patient returned to active nursing duty. Examination on March 21, 1960, showed her to be completely asymptomatic and the hip to be normal except for a loss of 50 per cent of rotation.

Note, in Figs. 6-C and 6-D, the great contrast with Figs. 5-A and 5-B in size and position of the hip shelf. As of March 21, 1960, both hips showed minimum evidence of degenerative arthritis.

eighteen patients (twenty-four hips). This technique provides complete stability of the shelf without sutures or other fixation. Through a curved incision along the iliac crest (Fig. 4-A), the gluteus medius and minimus muscles are elevated subperiosteally from the ilium and these muscles, together with the reflected head of the rectus femoris muscle, are dissected off the anterior and superior aspects of the capsule so as to form a pocket between them and the capsule. The capsule is thus left intact to serve as a buffer between the femoral head and the shelf. Direct contact between the shelf and the femoral head must be avoided since this may lead to late traumatic changes.

FIG. 7-A
August 16, 1954

FIG. 7-B
May 26, 1959

FIG. 7-C
May 26, 1959

FIG. 8
May 24, 1960

Figs. 7-A, 7-B, and 7-C: This policeman, fifty-six years old at time of admission, had been so incapacitated by increasing osteo-arthritis and pain in his left hip that he had requested a furlough from the police force. He had continuous pain, marked reduction of motion in abduction and rotation, and a severe limp.

A hip shelf was implanted on October 31, 1955. The patient was hospitalized for seventeen days; he then used crutches for six weeks and a cane for seven months. He returned to police duty one year after operation.

At follow-up, on September 20, 1960, five years after operation, the patient was still active in the police force. Range of motion had remained essentially unchanged. After a full day of activity on his feet, he experienced no pain or spasm. However, this result may be temporary.

(Legend for Fig. 8 is at top of page 104)

Fig. 8: Follow-up roentgenogram made on May 24, 1960, of a woman with congenital dislocation of the right hip, who was forty-eight years old when first seen by us. She had had several operative procedures at various times prior to admission. She had marked pain, a limp, and limitation of motion of the hip of approximately 40 per cent.

A shelf was implanted on January 1, 1954. At follow-up, on May 24, 1960, she was still walking without support, although prior to operation she had always used two canes. However, pain was still present, presumably because of the cystic changes in the femoral head and osteo-arthritis of the hip. We suggested a prosthesis, but the patient refused.

FIG. 9-A

August 23, 1949

FIG. 9-B

October 7, 1959

Figs. 9-A and 9-B: This woman, with congenital dislocation of the left hip, was forty-five years old when first seen by us. She had been operated on twice during childhood. On admission, she complained of fatigue, instability of the hip, and pain while walking.

A shelf was implanted on August 19, 1948. Because of the light texture and thinness of the graft at the time of application, Russell traction was used for five weeks. The patient then used crutches for seven weeks and a cane for two years. The shelf fractured ten months after insertion.

At follow-up on October 7, 1959, the fracture had united and the patient was still ambulatory. She was fully active, had no pain, and a barely perceptible limp.

A large rectangular graft, approximately nine by six centimeters, is removed from the external table of the ilium (Fig. 4-B). By taking the graft from this area, the curved external surface of the anterior ilium is included in the graft. With this surface down the graft will conform to the shape of the femoral head when the shelf is in place. Sufficient length of the graft is obtained by extending it posteriorly along the ilium as necessary. After removal of the graft, a slot is cut into or through the ilium, starting just above and slightly behind the superior surface of the head of the femur. In doing this, the osteotome is directed upward and backward. When a slot of adequate size has been prepared, the end of the graft, originally located in the anterior ilium, is placed in the pocket beneath the gluteus minimus and medius muscles and the reflected head of the rectus femoris, with the concave cortical surface of the graft in contact with the capsule. The posterior end of the graft now projects upward toward the ilium. This is slid downward along the external surface of the ilium and snapped into the previously prepared slot. To accomplish this it may be necessary to shorten the graft somewhat, using rongeurs to nibble away the proximal end (Fig. 4-B). Since the slot

in the ilium is placed slightly behind the femoral head, the shelf extends outward and forward and hence does not abut against the greater trochanter. When properly fitted it is almost impossible to remove the shelf once it has been snapped into place. The outer portion of the shelf makes contact with the femoral head and intervening capsule, frequently leaving a triangular space bounded by the shelf, the ilium, and the capsule. This space may be disregarded. After the shelf is in place the wound is closed, suturing the fascia of the thigh and gluteal muscles back in place on the iliac crest. This helps to retain the graft in place.

A shelf implanted in this fashion usually increases in thickness and may even be remodeled to conform to the shape of the femoral head beneath it (Figs. 5-A through 6-D).

After closure of the wound a simple dressing is applied and the legs are bandaged together until the patient recovers from anesthesia. The bandages may be removed then or within a few days and no plaster or other form of immobilization is used. The patient is otherwise allowed to be free in bed until the wound is healed.

RATIONALE OF THE HIP-SHELF OPERATION

1. The shelf forms a buttress above the femoral head and thereby provides stability.

2. The shelf with the underlying capsule increases the weight-bearing surface of the true or false acetabulum, as the case may be; stops the tendency of the femoral head to migrate or subluxate upward; and decreases the tendency of the femoral head to become deformed.

3. The presence of the shelf improves the function of the gluteal muscles because a stable fulcrum is formed and the efficiency of these muscles is enhanced. It is presumed that with the shelf in place, the gluteal muscles are stretched over its outer edge, with the result that their direction of pull and length-tension relationships are improved.

4. The dissection over the superior aspect of the capsule may sufficiently denervate the hip to relieve pain after operation. The presence of the shelf in immediate contact with the capsule may prolong the effect of this denervation, providing a mechanical block to the regeneration of nerves.

RESULTS

The results in this study were rated as *excellent*, *good*, or *poor*. Patients with excellent results had no pain, no fatigue, and no tendency for their hips to tire easily. When last examined, their hip joints were perfectly stable and their gaits were markedly improved although still not normal in the patients with dislocated hips. Patients with good results were able to engage in the regular activities of a normal life, but they had mild pain and fatigue in the hip. All patients with results less satisfactory than these were rated as *poor*, even though all were at least temporarily improved after the operation.

All of the patients eventually discarded all supportive apparatus, at least for a period of time. Four now periodically use a cane. Two of these four, both with bilateral shelves for inadequate acetabula, coxa magna, and established degenerative arthritis, had a Thompson prosthesis implanted in one hip. At the time of this study one of these patients had been followed for fifteen months; the other had been followed for one year. In each instance the shelf is still present and appears to be forming a solid bone buttress over the prosthesis (Figs. 2-A through 3-E). The results of both of these replacement procedures are satisfactory thus far and the opposite hips have remained stable without pain.

No other revisions (hip fusion, osteotomy, or reconstruction) have been necessary after the shelf procedures, although, of course, as time goes on, and degenerative changes occur, other patients may need additional surgical treatment. It is of interest in this connection that the woman with paralytic dislocation of the hip and absence of the femoral head still has an excellent result twenty-four years after shelf operation.

Of the two patients with coxa magna and advanced arthritic changes, one remained completely asymptomatic for ten years and then two years ago, pain in the hip developed quite suddenly. During the ten years he worked as a freight-elevator operator doing heavy manual labor, moving heavy doors and handling freight. After recurrence of pain he changed his job to one more suitable for his hip disability. Since becoming a passenger-elevator operator he has been comfortable. The other patient with coxa magna, a policeman on full active duty, is without symptoms over five years after operation. Flexion and extension of the hip are normal, but the other motions are markedly limited (Figs. 7-A, 7-B, and 7-C).

In the fifteen cases of subluxation of the hip (dysplasia of the acetabulum and coxa magna) there were eleven excellent and two good results. In the two remaining patients degenerative changes and pain necessitated further treatment and prostheses were inserted. One of the patients with a good result continues to have pain. Cystic degeneration of the femoral head, present before the shelf operation was performed, may explain the persistence of pain (Fig. 8).

In the twenty-eight congenital dislocations of the hip there were eighteen excellent results, seven good results, and one poor result after shelf operation. In the patient with the poor result pain has gradually recurred during the ten years since operation. In this woman, who is five feet, three inches tall and weighs 195 pounds, the hip has remained stable with an excellent range of motion despite the pain.

Follow-up roentgenograms of all the hips in this series revealed that all the shelves united to the ilium and only one shelf, implanted before 1946, showed any absorption. In this instance there was partial absorption of the outer end of the shelf in a hip in which a previous arthrodesis had failed and left considerable scar tissue. The distal end of the shelf where absorption occurred lay in this scar tissue. At a second shelf operation the scar tissue was removed and a new shelf applied on top of the partially absorbed first shelf. This shelf was incorporated and remained intact; the final result was excellent.

Two grafts fractured ten months and three months, respectively, after operation. Both fractures healed while the patients continued to be active, walking with canes, and were united, as seen by roentgenograms six months later (Figs. 9-A and 9-B).

CONCLUSIONS

1. In an old congenital dislocation of the hip in an adult, an adequate shelf operation will, in a high percentage of cases, establish an adequate dome of bone over the femoral head and relieve symptoms.

2. In congenital subluxation of the hip, or acetabular dysplasia and coxa magna, in an adult without advanced degenerative changes, an adequate shelf may alleviate symptoms and delay the development of further degenerative changes. Under these circumstances this procedure may have value as both a prophylactic and a therapeutic measure.

3. In malum coxae senilis or coxa magna with advanced degenerative changes a shelf may be indicated for the relief of pain when more extensive reconstructive surgery is inadvisable. However, only two patients in this series were treated in this fashion.

Cystic Lymphangiectasis of Bone

A Case Report

BY JOHN T. HAYES, M.D., AND GERALD L. BRODY, M.D., ANN ARBOR, MICHIGAN

From the Departments of Orthopaedics and Pathology, The University of Michigan Medical Center, Ann Arbor

This report describes an unusual case of demineralizing bone disease in an adolescent boy. Considerable difficulty was encountered in establishing a diagnosis until numerous biopsy specimens were obtained. Many diffuse and sharply localized areas of skeletal demineralization were noted in the roentgenograms (Figs. 1, 2, and 3). The roentgenographic picture was further confused by the presence of rachitic-like changes in several of the epiphyseal lines (Fig. 1). The left lower extremity was longer than the right, and there was definite thickening of the skin and subcutaneous tissue of the left calf, thigh, and external genitalia.

FIG. 1

Roentgenogram of the hands. A lesion is present in the second right metacarpal bone. Rachitic-like changes are present in the distal portion of the ulna in both wrists.

CASE REPORT

The patient (F.F. #884547), a boy eleven years old, was admitted to the University of Michigan Hospital on October 24, 1957, with a history of numerous recent fractures of the right femur. The most recent fracture had resulted from very minimum trauma to the right thigh.

The patient was born in Germany on September 27, 1946; his early development had been normal. At about two years of age, a progressive bilateral genu valgum was first noted. He had none of the physical signs of osteogenesis imperfecta. Roentgenograms, made on September 9, 1949, revealed slight coxa valga, widening of the medullary canals of both femora, several lytic areas in the distal end of the right femur, and marked irregularity of the provisional zone of calcification of the distal portion of the left femur.

FIG. 2

Anteroposterior roentgenogram of the pelvis and upper ends of the femora. There are widespread cystic changes. Note the flattening of the right femoral head.

FIG. 3

Roentgenogram of the knees. Extensive cystic changes are visible in the femora and tibiae.

The lesions in the femora continued to increase in size, and the valgus deformity of the knees also progressed. At the age of three years, enlargement of the scrotum and of the soft tissues of the left lower extremity became apparent. The serum calcium, phosphorus, and alkaline-phosphatase levels were within normal limits. Vitamin D was administered without effect on the osseous lesions.

FIG. 4

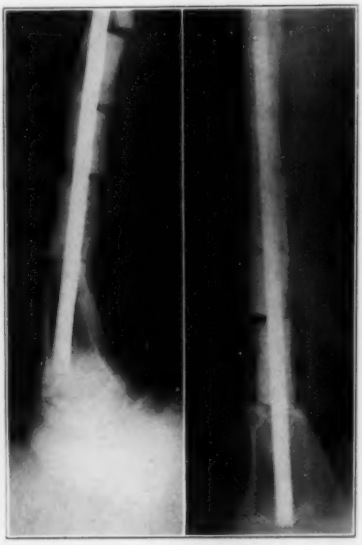

FIG. 5

Fig. 4: Anteroposterior and lateral roentgenograms of the right femur. A marked anterolateral bowing deformity is present. There have been numerous fractures through the area of maximum bowing.

Fig. 5: Anteroposterior and lateral roentgenograms of the right femur soon after operative fragmentation, realignment, and fixation with an intramedullary rod.

In July 1950, when the child was almost four years old, osteotomies of the distal portion of the femora were performed in Germany to correct the genu valgum, but the deformity recurred and progressed in both knees, and serial roentgenograms showed recurrence and progression of the cystlike lesions in the femora and tibiae. Two years after operation, when the child was six years old, the bone age was normal, but demineralization of bone with cystic lesions was still present and increasing. Progressive thickening of the subcutaneous tissues of the left lower extremity and the scrotum was also noted, as well as hyperpigmentation of the skin. Intravenous pyelograms were normal.

During 1956 and 1957, when the child was ten years old, several fractures of the right femur occurred after only slight trauma, and very severe anterolateral bowing of the right femur developed (Fig. 4).

Physical examination at the time of admission to the University of Michigan Hospital when the patient was eleven years old revealed bilateral genu valgum of approximately 20 degrees and marked anterolateral bowing of the right femur. The left limb was four inches longer and three and one-half inches larger in circumference at the mid-thigh than the right. The soft tissues of the left lower extremity were thickened and indurated but did not exhibit pitting edema. There were some patchy areas of hyperpigmentation in the skin of the lower extremities and the scrotum. A number of prominent small veins were noted in the subcutaneous tissue both above and below the left knee along the course of the saphenous vein. A few were seen just below the knee anterolaterally. The scrotum was grossly thickened (Fig. 8).

Roentgenograms of the skeleton revealed extensive and widespread demineralization of the long bones. Cystic changes were seen in the pelvis, femora, and tibiae (Figs. 1, 2, 3, and 4). Less extensive changes were seen in the humeri and bones of the hands. Calcium balance studies were normal. The renal amino-acid excretion pattern was normal except for a slight increase in valine. There was nothing to suggest the gross amino-aciduria of Fanconi's syndrome. Serum calcium, phosphorus, lipid, and phospholipid levels were normal. A punch biopsy of the scrotum was obtained. Because of the many foam cells in the dermis this tissue resembled a xanthoma of the skin. A biopsy of the right greater trochanter showed some absorption of cortical bone with focal fibrosis in the marrow spaces. The changes were considered most consistent with, although not diagnostic of, fibrous dysplasia.

From November 1957 to October 1958, the patient was followed periodically, and the leg-length discrepancy was noted to increase to four and one-half inches. During this period, he was

FIG. 6

FIG. 7

Fig. 6: Two months after operation there is evidence of reconstruction of the cortical tube of the femoral shaft.

Fig. 7: Eight months after operation, the femur is reconstructed.

placed on 7,500 units of vitamin D a day, with no response. Unsupported ambulation was not allowed because of the danger of fracture of the right femur. The following corrective orthopaedic procedures were advised: (1) a Sofield [10] procedure (multiple osteotomy and intramedullary fixation) for the right femur, (2) osteotomy of the right femur and tibia to correct the valgus deformity of the right knee, (3) osteotomy of the left femur and tibia to correct the valgus deformity of the left knee, and (4) an epiphyseodesis of the proximal left tibial and distal left femoral epiphyses to overcome the leg-length discrepancy.

On March 4, 1959, the grossly deformed right femur was straightened by means of several osteotomies. A Küntscher intramedullary nail, nine millimeters in diameter, was utilized for fixation (Fig. 5). Excellent bone healing with reconstitution of the cortical tube of the shaft of the femur followed this operation (Figs. 6 and 7). Biopsies of bone from the right femur at this procedure shed no further light on the diagnosis.

On May 20, 1959, the patient was allowed to walk with crutches. The leg-length discrepancy was now three inches, and bilateral genu valgum was still present (Figs. 8, 9-A, and 9-B).

On August 12, 1959, epiphyseodesis of the distal epiphysis of the left femur and of the proximal epiphyses of the left tibia and fibula was done. In addition, osteotomies of the distal portion of the left femur and proximal portion of the left tibia were done to correct the valgus deformity of the left knee, and osteotomy of the proximal portion of the right tibia was performed to correct the valgus deformity of this knee. At the time of these operative procedures, several interesting gross pathological findings were noted in the left lower limb. Wherever any of the tissues were incised, turbid lymphatic fluid oozed from the cut surfaces. This fluid was seen in subcutaneous tissues, muscle, and bone; it seemed to well up from many capillary-sized lymphatic vessels. Several soft, yellow, loculated lesions were seen in the tibia and the femur. There was no compact bone found in the shaft of the tibia or the femur; rather, the cortex had been replaced by a layer

FIG. 8

FIG. 9-A

FIG. 9-B

Fig. 8: The patient in August 1959, shortly before his thirteenth birthday. The deformity of the right femur has been corrected. The left lower extremity is three and one-fourth inches longer and three and one-half inches greater in circumference at the mid-thigh level than is the right. Bilateral genu valgum is present. The scrotum is greatly thickened.

Figs. 9-A and 9-B: Roentgenograms of the knees. Bilateral genu valgum is present. Numerous cystic lesions are present in the tibiae.

of very coarse, porous, trabecular bone. Several bone and soft-tissue biopsy specimens were taken.

After the lower extremities had been in plaster for two months, the osteotomies were healed, and the patient was permitted to walk (Fig. 10). At the last examination, on January 28, 1960, when the boy was thirteen years old, the leg-length discrepancy had diminished to two and one-half inches (Fig. 11).

PATHOLOGICAL FINDINGS

The tissue specimens, which were obtained on four occasions over a two-year period, consisted of several biopsies of skin and bone. The bone specimens included curettings from cysts and small excised blocks of cortical and cancellous bone. The biopsy specimens were obtained as follows: greater trochanter of the right femur on November 11, 1957, when the patient was eleven years old; shaft of the right femur on March 4, 1959, when the patient was twelve years and six months old; left femur, right and left tibiae, and proximal epiphyseal plate of the left tibia on August 12, 1959, when the patient was twelve years and eleven months old.

Grossly, the soft tissue and the curettings were unremarkable. The specimen of tibia removed at the last operation contained small cysts up to 1.5 centimeters in greatest diameter. The walls of these cysts were eggshell-thin; the cysts appeared to be empty and they had no obvious linings. The bone between the cysts was normal in texture.

Microscopically, the cysts were lined by a single layer of flat endothelial cells overlying a very scant amount of delicate fibrous connective tissue. The lumens of the cysts did not contain erythrocytes, and no smooth muscle was

FIG. 10

FIG. 11

Fig. 10: Anteroposterior roentgenogram ten weeks after corrective osteotomies of both tibiae and the left femur, revealing that many of the cystic lesions in the tibiae have disappeared.

Fig. 11: Photograph (October 23, 1959) of the patient ten weeks after correction of the angular deformities. The legs are now straight. A discrepancy in the length of the lower extremities persists, but this is decreasing as a result of epiphyseodesis of the distal portion of the left femur and upper portion of the tibia.

present in their walls (Figs. 12 and 13). Osteoclastic-bone absorption was not evident; the cystic spaces appeared to have developed as a result of pressure atrophy of the trabeculae. The surrounding marrow spaces contained the usual adipose tissue, and, close to the epiphyses, the marrow showed normal hematopoietic activity. There was minimum patchy fibrosis of the marrow spaces in some areas but not like that in fibrous dysplasia. The periosteum was thickened and contained dilated lymphatics, of which some were cystic. The skin and subcutaneous tissues likewise contained many dilated lymphatic channels (Fig. 14); in addition, there were many thick-walled arteries and veins of the type seen in congenital arteriovenous shunts. There was evidence of angioblastic proliferation in the skin and subcutaneous tissues; however, arteries and veins were not present within the bone. Many foam cells were present within and adjacent to the vascular spaces (Fig. 15). The foam cells appeared to be originating at these sites. In other areas there was evidence of old hemorrhage with hemosiderin-containing macrophages: foam cells were present in these areas and were typical of the usual lipid-containing histiocyte or macrophage; they were not present within the bone.

DISCUSSION

The diagnosis in this case was not made until several biopsy specimens had been obtained. Although the diagnostic dilated spaces were present in some of the earlier material, their appearance was so unremarkable that they were easily overlooked. Similar difficulties in establishing a diagnosis were noted by others [3,9].

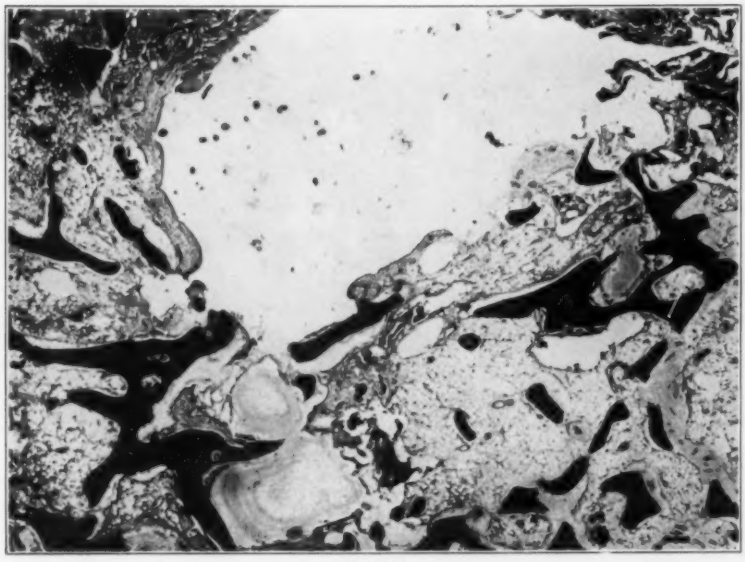

FIG. 12

A photomicrograph of a section from the upper portion of the left tibia, showing large, thin-walled cystic lymphatic spaces between the trabeculae. Several smaller cystic spaces are to be seen in the right half of the photomicrograph (hematoxylin and eosin, × 15).

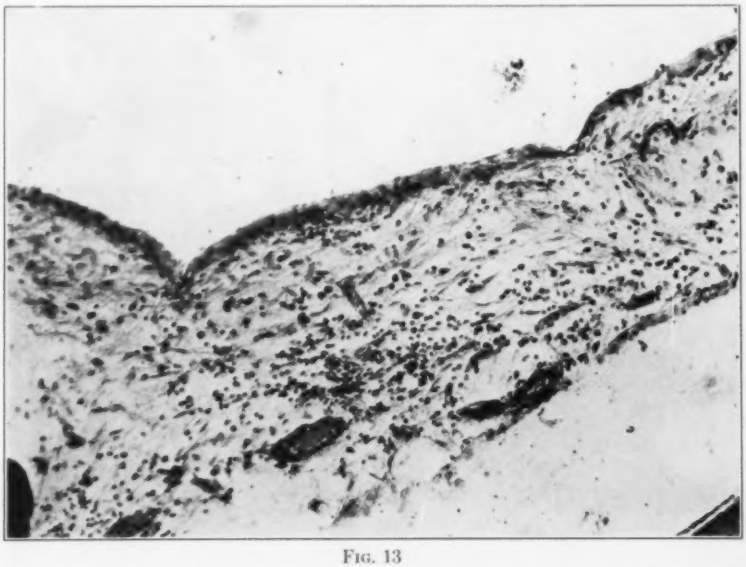

FIG. 13

A higher-power photomicrograph of the wall of a cyst. No smooth muscle is present within the wall, and there are no erythrocytes in the lumen (hematoxylin and eosin, × 90).

Because the spaces did not contain blood, because, at operation, turbid, milky fluid typical of lymph welled up from them, and because their walls were devoid of smooth muscle, it was concluded that they were lymphatic in nature. The appearance of these spaces corresponded closely to that of the lymphatic cysts

FIG. 14

Biopsy of the skin from the scrotum. The photomicrograph shows dilated subepidermal lymphatics. Several collapsed lymphatics are also present deeper in the dermis (hematoxylin and eosin, × 90).

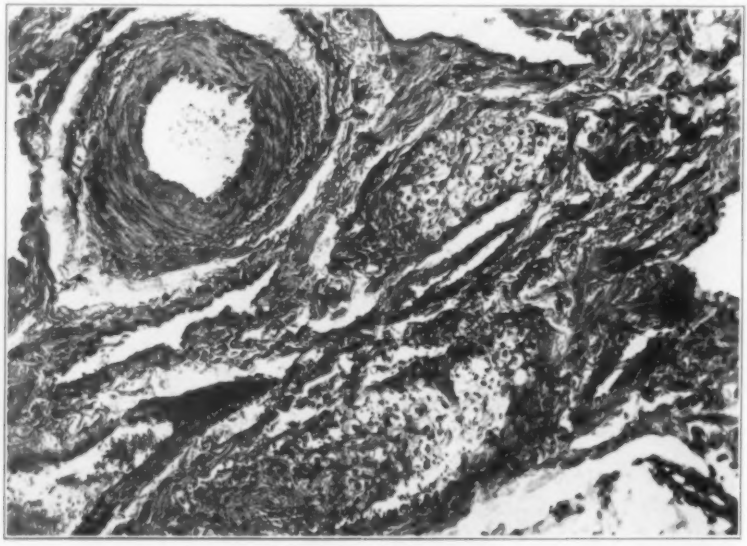

FIG. 15

Photomicrograph of T section from the subcutis over the proximal portion of the left tibia. Two clusters of foam cells can be seen adjacent to the artery; in some areas these foam cells lie directly under the endothelium of thin-walled vascular spaces (hematoxylin and eosin, × 85).

seen in other reported cases [6]. In the present case the dilated lymphatics were part of a malformation that involved arteries and veins as well. The appearance of the bone lesions when the child was two years of age, the generalized involvement of the skeleton, and the histological appearance of the arteriovenous complexes lead to the conclusion that this condition represented a congenital vascular

malformation. The production of numerous cysts by lymphangiectatic vessels is believed to be a manifestation of a lymphatic component of the vascular malformation. The numerous bone cysts are thought to be produced by progressive dilatation of the lymphatics with gradual absorption of the adjacent bone trabeculae. Successive roentgenograms showed that new cysts formed in areas that were apparently uninvolved when the patient was younger.

The increased length of the left lower extremity of this boy is thought to have been caused by the increased blood supply consequent to the arteriovenous abnormalities, whereas the thickened, leathery skin and subcutaneous tissue of the extremity and scrotum are attributed to the dilated lymphatics. Because dilated lymphatics were present within the bones, and abnormal arteries and veins were not, this case had been designated as cystic lymphangiectasis of bone, occurring as a manifestation of an anomaly of the vascular system.

The articles by Jacobs and Kimmelstiel and by Cohen and Craig contain excellent discussions of the nature of these lesions and bring out clearly the difficulties of exact classification. The pathological lesions vary from case to case with respect to the proportions of the different vascular components present and, more importantly, with respect to the evidence of actual proliferative activity. Whether a given case should be regarded as a hamartoma—that is, a tumor-like malformation—or as a congenital anomaly is difficult to determine. In this case the skin and subcutaneous tissue of the scrotum and lower extremity were both the sites of gigantism. In these sites there was evidence of proliferation of the blood vessels, and here the diagnosis of angiohamartoma seemed justified. In the bones, however, there was no evidence of such proliferation; the lymphatics alone were dilated. Thus, insofar as the bone lesions are concerned, the designation of cystic lymphangiectasis seemed to be appropriate. The presence of such lymphatics within bone is anomalous, and this is considered to be further support for the concept that this lesion represents a congenital malformation.

Exactly how these lymphatics gain entry into bone is not clear. The periosteum contains similar cystic vessels. Cohen and Craig and Falkmer and Tilling noted these cysts in the periosteum also and suggested that they entered the bone by way of the adventitia of the nutrient arteries as these arteries pass through dilated nutrient foramina. Our biopsy material is insufficient either to confirm or to deny this concept.

There are two other intriguing aspects of this rare disorder that deserve mention.

The first is that the presence of lipid-containing histiocytes with numerous cystic lesions of bone might represent an aberrant form of one of the reticuloendothelioses. Similar foam cells were noted by Parsons and Ebbs and by Bucy and Capp; the clinical course of the case of Parsons and Ebbs closely simulated that of Gaucher's disease. These authors cited the European concept that numerous angiomata are a form of reticulo-endotheliosis in the sense that they represent a proliferation of the endothelial-cell component of the reticulo-endothelial system. However, there was no evidence in the present case to support such a concept. The cystic spaces in bone did not contain histiocytes, eosinophils, or cells of the type found in lipid-storage disease. There were no clinical findings to suggest Hand-Schüller-Christian disease, Letterer-Siwe disease, or other lipidoses. The serum lipid levels were normal. The presence of foam cells closely associated with vascular spaces and areas of old hemorrhage suggested that their presence is secondary and that their function was normal—namely, the phagocytosis or imbibition of lipids, probably derived from the blood.

The second is that cystic lymphangiectasis of bone may represent a phase

of the syndrome known as disappearing bones. It is of interest in this regard that the first reported case of primary lymphangioma of bone, that of Bickel and Broders, was later considered to be disappearing bone [5]. The recent case of Falkmer and Tilling suggested a transition between the two conditions. Gorham and Stout suggested that disappearing bone was the result of a hemangiomatosis, although Milner and Baker disagreed. The condition reported in our case had some features in common with disappearing bones—namely, the presence of dilated vascular spaces within bones. However, in disappearing bones there is more proliferation of blood vessels within and adjacent to bone than was found in our material. It may be that these differences are quantitative and not qualitative and that the diseases will be found to be related. Clinically, cystic lymphangiectasis is quite different from disappearing bones, in that there is no massive osteolysis, fractures heal promptly—a situation certainly not found in disappearing bones—and there are numerous small cysts throughout the skeleton. For the present, at least, it seems advisable to keep the two diseases separate.

The rachitic-like changes (widening of the epiphyseal line and irregular demineralization of the zone of provisional calcification), which were best seen in this case in the distal end of the ulna, are difficult to explain (Fig. 1). A biopsy specimen of the proximal tibial epiphyseal plate (left tibia, August 8, 1959) showed increased length of columns of chondrocytes and increased vascularity of the cartilage. Cystic lymphatic channels were seen in a biopsy specimen of the femoral trochanteric epiphysis. These channels are thought to be responsible for the rachitic-like changes, but the mechanism is not understood. Ossification of the left tibial epiphysis itself was far-advanced, although somewhat irregular, with persistent islands of cartilage still undergoing ossification.

In our review of the roentgenograms from Germany made during the patient's childhood, we found definite evidence of recurrence of the cystic lesions in the distal portion of both femora at the site of the previous osteotomies. In addition, roentgenograms made in the years 1950 through 1956 showed new cystic lesions appearing in both femora and both tibiae, as well as in the humeri, hands, and pelvis. During the two and one-half years we had the patient under observation we saw no new lesions. In fact, after each of the recent operations, in which the periosteum was elevated, new healthy cortical bone was laid down, and the lesions did not recur (Figs. 7 and 10). This suggests that the process is becoming arrested as the patient nears skeletal maturity. We suggested to the parents that once the boy reaches sexual maturity and growth ceases, the deformities will probably stop; we cannot, however, substantiate this hypothesis with any firm evidence.

In February 1960, when the boy was thirteen years old, he returned to Germany. He is now walking normally and attends school regularly. During the period of our observation of this patient from October 1957 to February 1960 (from the patient's eleventh to thirteenth year of age) we found no objective evidence of progression of the lesions.

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Serpentine Sinus—A Tract Leading Nowhere

Congenital Peripheral Dermal Tract

BY RALPH LUSSKIN, M.D., NEW YORK, N.Y.

From the Orthopaedic Service, Lenox Hill Hospital, New York

This paper describes an unusual form of congenital anomaly, a long peripheral dermal sinus tract. Goff does not mention this disorder in his review of congenital malformations. In their discussion of congenital skin lesions, Ombrédanne and Lacassie described ulcerations, dimplings, constriction bands, facial scars, and necrotic sloughs, but no well organized sinuses. Ombrédanne and Lacassie carefully evaluated the role of amnionic bands and discarded the concept of a mechanical etiology of these lesions as in no way explaining the other abnormalities, such as absence of bones, polydactylism, and syndactylism, that are so frequently associated with these congenital skin lesions. The concept of an intra-uterine ulcerative process occurring early in fetal life was advanced by these authors, who strongly supported the concept that the abnormalities in the amnion were preceded by abnormalities in the fetus. This concept is now widely accepted.

A congenital dermal sinus is usually described as a tract lined with skin that leads from the surface of the body into, or toward, a structure that was, at some time in embryonal life, normally connected with the body surface. It is usually assumed that a dermal tract is formed, when, for some reason, a normal obliterative process fails to take place. Sinuses of this type are encountered quite frequently in the sacral region, where the rhomboid sinus may appear as a pilonidal sinus or sacral meningeal cyst, and, in the neck, where the branchial clefts may remain as cervical cysts or fistulae. Peripheral sinuses are usually the result of infection or are no more than superficial dimplings associated with skeletal anomalies, such as congenital bowing or pseudarthrosis of the tibia and absence of bones. Dimpling is seen in congenital amputation, as well. Judging from the absence of reports in the literature, long congenital dermal tracts that are located in the peripheral portion of a limb and follow a longitudinal course are rare. If one accepts the theory that constriction bands and other cutaneous congenital anomalies are the result of localized arrests of ectodermal development, with or without necrosis, ulceration, and cicatrization of tissues that developed prior to the arrest of development, the mechanism of origin of a long tract in the foot, like the one to be reported here, presents a baffling problem. This anomaly does not fit the pattern of development envisioned by this hypothesis.

CASE REPORT

R.L., a white boy, twelve years old, was first admitted to the Lenox Hill Hospital on December 12, 1957, with recurrent swelling of the medial aspect of the left ankle that had been present since September 1957. The patient had asthma, and his past history revealed that during the first year of his life he had had an episode of osteomyelitis involving the proximal ends of both humeri. Treatment with penicillin alone had been successful. There had been no drainage and no recurrence since that time. At birth, a small hole on the outer side of the left foot near the base of the fifth metatarsal had been noted. There were no other congenital abnormalities, and no member of his family had a similar abnormality. The small hole had never given cause for anxiety until September 1957, when a swelling developed behind the medial malleolus. In October, this swelling became hot, red, and tender. Incision and drainage was performed at another hospital. Pus was

obtained, and a staphylococcus sensitive to erythromycin was cultured. At this time, purulent drainage from the hole on the outer side of the foot was observed for the first time. Drainage ceased after treatment with erythromycin for one week. Roentgenograms showed no skeletal abnormality.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Site of incision and drainage behind the medial malleolus.
Fig. 1-B: Sinus opening at the base of the fifth metatarsal.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Lateral roentgenogram of the foot after injection of lipiodol.
Fig. 2-B: Anteroposterior roentgenogram of the ankle after injection of lipiodol in the sinus tract.

In November, the abscess recurred and once again subsided on erythromycin therapy. After another recurrence of the infection at Christmas time he was admitted to the Lenox Hill Hospital.

On admission, the patient had a low-grade fever, and examination revealed swelling, discoloration, warmth, and scarring from the previous incision in the region posterior to the medial malleolus (Fig. 1-A). There was no drainage from the sinus opening on the lateral aspect of the foot (Fig. 1-B). Roentgenograms of the foot revealed nothing abnormal. On December 31, 1957, incision and drainage of the abscess on the medial side of the foot was performed, and a quantity of yellow-red exudate was released. The wound healed slowly.

On January 3, 1958, pantopaque was instilled into the sinus opening at the base of the fifth metatarsal, and a serpentine tract, running posteriorly along the outer side of the foot, around the back of the heel superficial to the Achilles tendon, and up the posteromedial side of the ankle, was found. The tract seemed to end in the superficial tissues in the region of the old abscess (Figs. 2-A and 2-B).

Signs of inflammation in the foot gradually subsided with the use of hot soaks and gantrisin. A plaster-of-Paris leg cast was then applied, and the patient wore this for the month preceding readmission for definitive surgery.

On February 21, 1958, the old scar on the posteromedial aspect of the ankle was excised, and the incision was extended up the leg and down to the heel. A subcutaneous, fibrous, cordlike structure was found to run from the region of the old infection up the leg for approximately four inches. When this cordlike structure was opened, it was found to contain sebaceous material. Probing revealed that its lumen extended proximally, ending in a fan of subcutaneous fibrous strands (Fig. 3). Distally, the wall became attenuated in the region of the old sepsis on the medial side of the ankle. The tract was removed from the medial side of the leg and ankle, and the wound was closed, with a small drain left in place. Healing was uneventful.

FIG. 3

Appearance of the tract after it had been dissected out from the dermis.

On April 24, 1958, the sinus opening and the remaining portion of the tract, which ran around the posterior aspect of the heel, were removed through three small incisions after the sinus had been filled with methylene blue to facilitate dissection. Healing was uneventful (Figs. 4-A and 4-B).

Microscopic examination of the specimens showed that the tract was lined with stratified squamous epithelium, filled with keratohyaline material, and surrounded by a dense fibrous-tissue stroma in which there were varying amounts of lymphocytic infiltration (Fig. 5). The upper end of the sinus showed little evidence of inflammation. There was no histological evidence of tuberculosis.

Follow-up one year after the last operation showed that the patient was asymptomatic. The wounds were well healed; there was full range of ankle and subtalar motion without pain or weakness.

DISCUSSION

The development of this sinus is difficult to imagine. Gruenwald emphasized the great difficulty that arises when one attempts to determine the cause and development of a given malformation seen after birth. The origin of the anomaly described in this report does not seem to fit any of the current theories of etiology

FIG. 4-A

FIG. 4-B

Healed incisions.

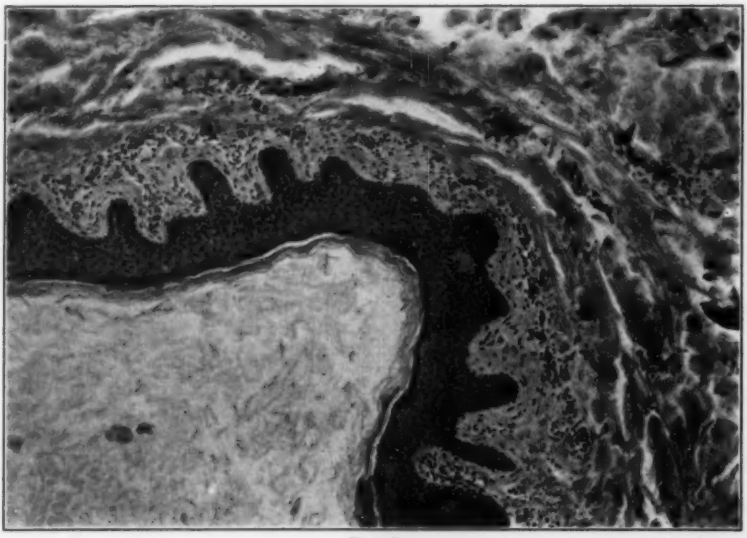

FIG. 5

Microphotograph of a portion of the sinus lumen, wall, and connective tissue. The lumen (lower left) is filled with keratohyaline debris. The fibrous stroma of the dermis is sparsely infiltrated by lymphocytes.

of congenital anomalies. These theories postulate that both intrinsic teratogenic influences in the genetic pattern and extrinsic influences operating through the maternal circulation either arrest or unduly prolong some normal process of differentiation or maturation. The ultimate effect of the teratogenic factor may be produced partly by the nature of the agent and partly by the pattern of sensi-

tivity of the embryo at the time that the agent is operational. The sinus found in this child's foot represents neither the failure of a normal obliterative process nor merely the result of simple local scarring. If, however, we postulate a local defect in the surface of the limb bud that became fixed so that it drew in or invaginated the surface as the limb bud grew, a longitudinal sinus like the one found here could have started. Once the invagination of the surface was established, the tract would increase in length with growth of the limb, and as rotation of the limb bud took place, the proximal portion of the sinus might remain fixed, while the distal portion of the tract, attached to the caudad edge of the limb bud, would deviate laterally as the limb bud rotated laterally. Thus, a sinus attached to the surface in the distal portion of the limb and ending in connective tissues proximally would take a tortuous path around the limb.

SUMMARY

An unusual serpentine, peripheral, congenital dermal sinus tract in the foot of a white boy, twelve years old, was treated successfully by excision. An attempt has been made to recapitulate the processes that led to the formation of the tract. It is postulated that this tract could have arisen from a local defect on the surface of the limb that, with growth of the limb bud and proliferation of ectodermal elements, became invaginated to form a sinus. Rotation of the limb bud might then have twisted the sinus about the leg, producing the tortuous course observed in the patient reported here.

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Primary Liposarcoma of Bone

Report of a Case and Review of the Literature

BY LOUIS D. RETZ, JR., M.D., SYRACUSE, NEW YORK

From the Department of Surgery, State University of New York, Upstate Medical Center, and the Surgical Service, Veterans Administration Hospital, Syracuse

Primary liposarcoma of bone has been reported* fourteen times [1-6,10,11,16,17,20] since Ewing [7] added this category to the classification of bone tumors in 1928. Since that time there has been considerable discussion as to whether this tumor may originate in the medullary cavity of bone [2,12,14,18]. In no previously reported case has the tumor been confined solely to the medullary cavity of a bone. The present report concerns a liposarcoma completely confined to the medullary cavity of the tibia.

C.C.M., a white male, forty years old, entered the Syracuse Veterans Administration Hospital on June 17, 1958, with the chief complaint of a dull ache, of three months' duration, along the upper anteromedial aspect of his left leg. The ache was relieved by aspirin, but it was exaggerated by activity. A month prior to admission the patient had noted some warmth in this area. There was no history of trauma, fever, weakness, or weight-loss.

The patient's past medical history and review of systems were non-contributory except for shrapnel wounds in his left thigh and foot. Both sites were asymptomatic.

Physical examination on admission revealed only a very slight asymmetry of the anteromedial aspect of the left upper tibial shaft, when compared with that on the right. There was no increased warmth in the area.

Laboratory examination showed a normal hemogram and urinalysis. Serum calcium, phosphorus, protein, and alkaline phosphatase levels were within normal limits. Roentgenograms, including laminograms of the left tibia (Fig. 1), revealed a well circumscribed central lytic defect in the upper metaphysis of the left tibia that measured five by four by four centimeters. The lesion did not penetrate the epiphyseal plate, and there was no expansion of the cortex or periosteal new-bone formation noted. The roentgenograms showed loss of the normal trabecular pattern within the confines of the lesion, but laterally and posteriorly the lesion presented a ground-glass appearance. The results of all the diagnostic studies were consistent with benign bone tumor. Chest roentgenograms and a skeletal survey were negative.

On June 30, 1958, a window was made in the somewhat thinned anterior cortex of the proximal part of the tibia, revealing yellow, lobulated, friable tissue. This tumor tissue was well demarcated from the normal-appearing marrow, but no true encapsulation was found. The tumor was removed by curettage, and the cavity was packed with bone from the right iliac crest. The patient's postoperative course was uneventful.

Microscopically, the tumor was a sarcoma containing many vacuolated cells with spindle-shaped nuclei. Sudan III stain revealed an abundance of intracellular lipid. There appeared areas typical of non-ossifying fibroma in close association with the sarcoma. The diagnosis was deferred. Slides of the tissue, along with a case summary and roentgenograms, were sent to the Armed Forces Institute of Pathology and to Dr. Henry L. Jaffe. The correspondence was completed in October 1958. Both of these authorities concurred in the diagnosis of primary liposarcoma of bone.

The staff at the Armed Forces Institute of Pathology regarded the lesion as a: "Sarcoma arising in what was originally a non-ossifying fibroma or fibroxanthoma. The sarcoma includes both spindled fibroblastic cells and fat cells of the ordinary fatty type and of the xanthomatous type. Since the lipid cells of both types dominate the picture, one is justified in using the term liposarcoma for a lesion of this type. There still remain some areas of typical non-ossifying fibroma which

* The two cases recorded by Geschickter and Copeland are not included since the tumors are not clearly identified as liposarcoma (Geschickter, C.F., and Copeland, M.M.: Tumors of Bone, p. 623. Philadelphia, J.B. Lippincott Co., 1949).

FIG. 1

Anteroposterior and lateral roentgenograms, made on admission, of the upper portion of the left tibia, showing the central lytic lesion in the metaphysis. Note areas of ground-glass appearance and the intact cortex.

merge imperceptibly with the sarcoma". It was Dr. Jaffe's opinion that: "The tissue pattern of the lesion is extremely puzzling for a tumor which has taken its departure in the medullary cavity of the upper end of the tibia. The lesion is obviously a sarcoma. Though I hesitate making a diagnosis of primary liposarcoma of bone, I believe that that is the most reasonable diagnosis to make in this case".

The patient re-entered the hospital on October 16, 1958. Roentgenographic examination showed further extension of the lytic area down the medullary cavity of the tibia (Fig. 2). On October 21, 1958, a mid-thigh amputation was performed. The gross specimen showed no soft-tissue tumor outside the bone. The cortex was unbroken except in the area of previous surgical intervention. Sagittal section of the tibia showed extension of the tumor distally in the medullary cavity (Fig. 3). Microscopic examination revealed similar tissue to that of the initial examination.

The patient's postoperative course was uneventful, and he is now walking with a suction-socket prosthesis. Systematic follow-up, including his last skeletal and chest survey two years after his original entry into the hospital, revealed no evidence of metastasis or recurrent tumor in the stump.

PATHOLOGY

Virchow in 1857 first described the microscopic appearance of liposarcoma. Ewing classified these tumors into two main types: (1) intermuscular myxoliposarcoma (vascular, myxoid, and lipoblastic) and (2) granular-cell lipoblastoma. Stout divided the classification of this tumor into four main categories: (1) well differentiated myxoid type, (2) poorly differentiated myxoid type, (3) round cell or adenoid type, and (4) the mixed type. In his opinion, the tumor arises from the lipoblast, an ordinarily specialized fat-forming mesenchymal cell which, on occasion, can produce a wide variety of different and complex tissues. Ewing [7] stated that liposarcoma primary in bone has no specific connection to the bone marrow, and therefore is not a true myeloma. It is also accepted that these tumors do not arise from pre-existing lipomata except under the rarest of conditions [13].

Grossly, when the tumor develops in the soft tissue it appears as a yellow or

FIG. 2

Roentgenograms of the upper portion of the left tibia fifteen weeks after curettage and bone-grafting. Note the slight extension of the lytic area distally in the shaft.

FIG. 3

Sagittal section of the amputated tibia shows recurrence of liposarcoma following curettage and bone-grafting. Note the slimy appearance of the tumor and extension distally in the medullary cavity. The cortex is intact and not expanded, save in the area of previous surgical intervention anteriorly.

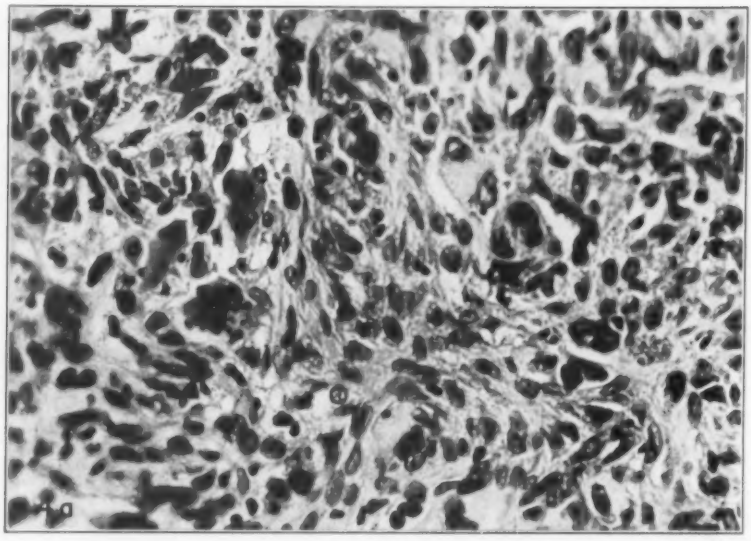

FIG. 4-A

Figs. 4-A, 4-B, 4-C, and 4-D: Four different sections of the tumor.
Fig. 4-A: Spindle-shaped cells of various sizes, many with large nuclei and vacuoles.

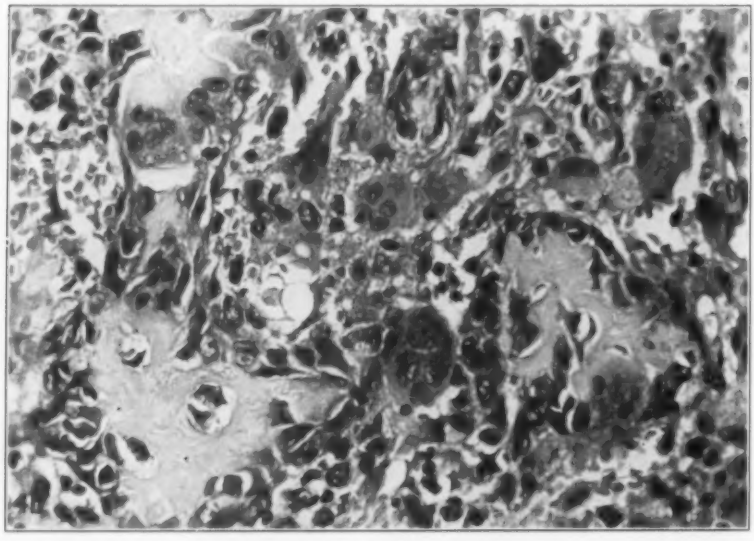

FIG. 4-B

Section showing new-bone formation. Note the non-sarcomatous multinucleated giant cells.

orange, more or less encapsulated, nodular mass. In bone it is well demarcated from the surrounding marrow, but no capsule is found. It usually has a fairly rich blood supply. The tumor tissue is firmer than that of a lipoma. On cut section the lesion may show varied areas, some that appear and feel slimy, and others that have a fibrous consistency. There may be hemorrhage and necrosis, but generally there are no cystic areas.

Microscopically, the more well differentiated tumors are composed of a mixture of mature fat cells and stellate or spindle-shaped lipoblasts in myxoid tissue. The cytoplasm of the lipoblasts shows small vacuoles containing lipid, and some may appear as "signet ring" cells because of a single large vacuole. Mitotic figures are not a prominent feature. These tumors are slow-growing and do not tend to metastasize, but they may recur if not adequately excised.

The less-differentiated tumors contain few, if any, mature fat cells and variable amounts of myxoid tissue. There is an abundance of lipoblasts which have a

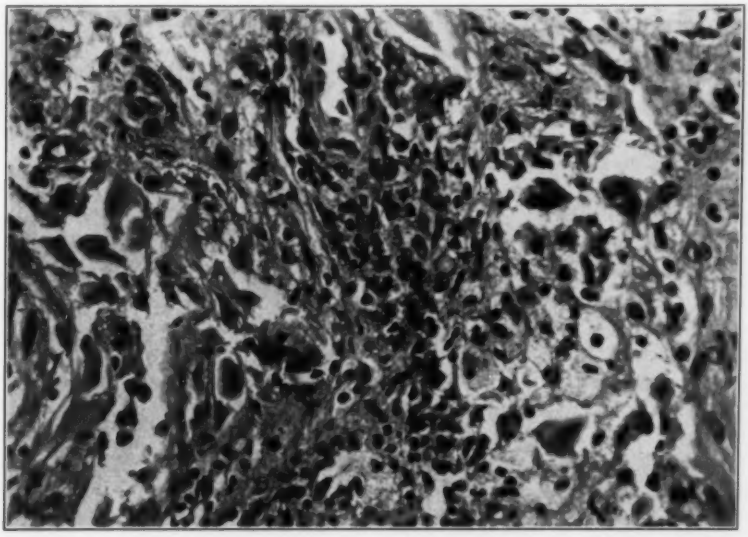

FIG. 4-C

Section showing foamy lipoblasts and giant sarcoma cells. Note lymphocytic infiltration.

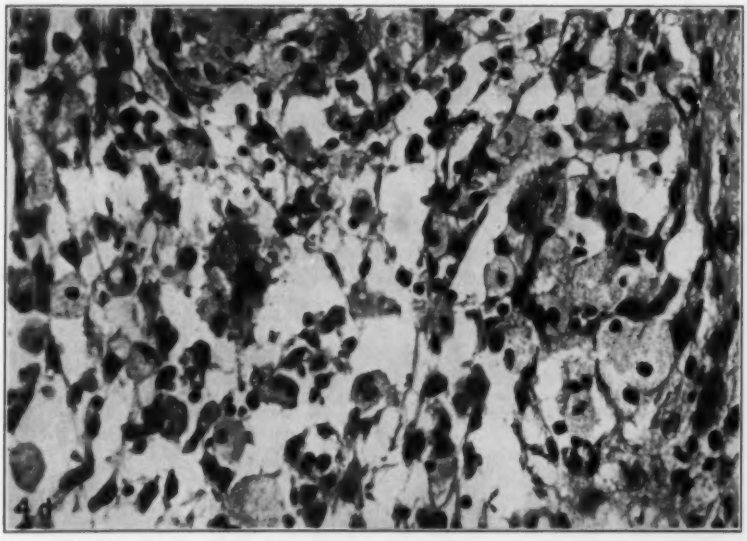

FIG. 4-D

Foamy lipoblasts in myxoid stroma. Note vacuolated tumor giant cell to the left of center.

bizarre appearance. Some may form multinucleated giant cells whose cytoplasm is vacuolated; others may appear quite anaplastic; and mitotic figures are frequent. Tumors that are free of myxoid tissue with rounded vacuolated lipoblasts appear to resemble brown fat. Other tumors may contain tissue representative of all the types just mentioned and as such be mixed in type. The poorly differentiated tumors carry a poor prognosis. They metastasize primarily through the blood stream, and metastases are commonly found in the lungs, other bones, and the brain.

The tumor in the case presented here is a fairly well differentiated liposarcoma (Figs. 4-A through 4-D). It contains spindle-shaped foamy lipoblasts and giant vacuolated sarcomatous cells, but the bizarre, vacuolated, multinuclear, giant cells, which are found in poorly differentiated liposarcomata, are absent. Mature fat cells are frequent, and mitotic figures are rare. The presence of considerable lymphocytic infiltration and the lack of necrosis, as are seen in this tumor, have been reported to indicate a favorable prognosis [12].

DISCUSSION

Lipomata may be found at any site in the body possessing adipose tissue. It is reasonable to assume then that liposarcomata may have equally widespread primary locations. In general, lipomata are found more frequently in the superficial soft tissues of the extremities, shoulders, and back. Liposarcomata, on the other hand, seem to be more frequent in the upper part of the thigh, popliteal space, gluteal region, and retroperitoneal space. These tumors are also found, although less frequently, in various other regions of the body; bone is one of the rarer sites of origin.

There are seven recorded cases of intramedullary lipoma [15] and fourteen recorded cases of liposarcoma arising in bone [1-6,10,11,16,17,20]. In a few of the latter cases there is doubt as to the site of origin of the tumors; they may have originated in the intramedullary space.

Of the seven reported cases of intramedullary lipoma, five arose in bones of the lower extremity, one in the upper extremity, and one in the skull [5]. Six cases of liposarcoma arising in bone were found in the lower extremity [3,5,6,10,16,17], three in the upper extremity [1,2,17], three in the pelvis and sacrum [11,16,20], and two of unknown primary site [4,17]. In not one of these cases was the tumor confined solely to the medullary cavity.

CONCLUSION

The case presented here would appear to be unique in that it clearly establishes the possibility of the intramedullary origin of a liposarcoma. Clinical, operative, and pathological examination of the extremity failed to reveal any evidence of tumor outside the medullary cavity of the tibia. Two years have passed, and the patient has shown no evidence of a primary lesion elsewhere or of metastatic disease.

NOTE: My thanks to J. Albert Schaefer, M.D., Chief of the Laboratory Service, Veterans Administration Hospital, Syracuse, New York, for his help in selecting the pathological sections presented, and to Robert O. Becker, M.D., Chief of the Orthopaedic Service, Veterans Administration Hospital, Syracuse, New York, for his critical review of the material presented.

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Pseudarthrosis of the Clavicle

A Report of Twenty Cases

BY HARILAOS SAKELLARIDES, M.D., BOSTON, MASSACHUSETTS

From the Orthopaedic and Fracture Services of the Massachusetts General Hospital, Boston

Most fractures of the clavicle unite readily despite the relatively inadequate immobilization afforded by a figure-of-eight bandage or the other methods of immobilization that are in common use. As far as can be determined, only thirty-nine cases of non-union of the clavicle have been reported [1,2,5,6].

It is the purpose of this communication to report a study of twenty cases of non-union of the clavicle investigated with particular emphasis on factors predisposing to pseudarthrosis, the clinical symptoms and complications associated with non-union, the types of surgical treatment employed, and the end results of treatment.

CLINICAL MATERIAL

Of the twenty cases included in this study, eighteen were seen at the Massachusetts General Hospital from 1915 to the present time, and two at the Croydon General Hospital in England.

In this study I have considered as ununited any fracture of the clavicle that was not healed four months after injury and that had (1) clinical signs of non-union (apparent motion at the fracture site and deformity) and (2) roentgenographic evidence of non-union.

Fifteen of the twenty patients were treated surgically by various methods, and five received no treatment. Fourteen patients were seen and examined by the author; information concerning the remaining six patients and their roentgenograms were obtained from the patients or their private physicians by correspondence.

There were eight female and twelve male patients whose ages at the time of fracture ranged from four to fifty-nine years, with an average age of twenty-eight

FIG. 1-A

FIG. 1-B

Figs. 1-A and 1-B: Case 20.
Fig. 1-A: Ununited fracture of the right clavicle nine years after it occurred. There were no symptoms whatsoever. The right shoulder had full, painless motion.
Fig. 1-B: Roentgenogram of the fracture.

years. Five patients were school children; the remaining patients had various occupations, among whom were housewives, clerks, and teachers. The fracture was on the right side in fourteen and on the left in six patients. The non-union had been present for from four months to four years in seventeen, and from eight to eighteen years in three patients.

Five of the twenty pseudarthroses were not treated (Table I) because of a severe associated brachial-plexus injury in two patients (Cases 16 and 17), because of minimum symptoms in two patients (Cases 18 and 19), and because one patient refused treatment (Case 20) (Figs. 1-A and 1-B).

FACTORS PREDISPOSING TO NON-UNION

The predisposing factors considered in this study were the severity of the trauma, primary open reduction, duration of immobilization, degree of displacement of the fragments, and location of the fracture.

Severity of Trauma

The trauma producing the fracture was graded as *severe*, *moderate*, or *mild*. Severe trauma included major violence, such as an automobile accident; moderate trauma included such injuries as falls from a bicycle or ladder, and athletic injuries; and mild trauma consisted of falls out of bed or a chair, or falls on the outstretched hand.

In this series, nine fractures were the result of severe trauma. Three followed moderate trauma; and three were caused by mild trauma. The remaining five pseudarthroses were considered to be congenital. In the cases classified as congenital the deformity had been present since birth, there was no history of trauma, and there were no clinical manifestations of neurofibromatosis [2,5].

Primary Open Reduction

Two of the fifteen non-unions followed primary open reduction. In one patient (Case 4) the fracture was fixed primarily with a circumferential wire with resultant non-union, and, one year later, the same procedure was repeated with the same result; the other patient (Case 8) had similar internal fixation, with failure to achieve union. The duration of immobilization in these two patients was only three to four weeks by means of a figure-of-eight bandage.

It is generally agreed that open reduction favors non-union [7], particularly if the internal fixation is not adequate.

Duration of Immobilization

Two of the fifteen patients had primary open reduction, and three had no immobilization at all. Six were treated with a figure-of-eight bandage, two with Velpeau bandages, and two with figure-of-eight plaster splints. Immobilization in these ten patients was continued for from three to four weeks, except in Case 1, in which it lasted for four and one-half months.

The period of immobilization recommended for this fracture varies from three to eight weeks [2,7]. It is possible that some of these fractures failed to unite because the period of immobilization was insufficient.

Gross Displacement of the Fragments

Persistent gross displacement of the fragments with a gap between the fracture surfaces or with soft-tissue interposition is thought to play some part in the establishment of the non-union. In four cases, the degree of the original displacement is unknown; in nine, there was marked overriding of the fragments, with a

TABLE I

DATA ON FIVE UNTREATED UNUNITED FRACTURES OF THE CLAVICLE

Case	Age (*Years*)	Sex	Side	Occupation	Cause of Lesion	Original Displacement and Location	Initial Treatment
16	23	M	R	Clerk	Motor-cycle accident	Overriding, mid-third	None
17	22	M	L	Clerk	Auto-mobile accident	Comminuted; open; piece of bone removed during débridement, junction of middle and outer thirds	Velpeau bandage, 5 wks.
18	20	F	R	Housewife	Softball accident	Overriding, mid-third	Figure-of-8 bandage, 4 wks.
19	34	F	R	Housewife	Fall	No displacement; junction of middle and outer thirds	None
20	21	M	R	Repairman	Automobile accident	Overriding, mid-third	Figure-of-8 bandage, 3 wks.

gap of one-half inch or more between them; in one, the fracture was very comminuted; and in the remaining one, the fracture was open and comminuted, and, during the original débridement, small, loose fragments of bone were removed. These findings suggest that marked displacement of the fragments with persistent gaps between the fragments plays a significant role in the development of non-union of the clavicle.

Location of the Fracture

Eight of ten fractures of the clavicle occur in the middle third [3]. Most of the fractures in this series were located in this site: sixteen in the mid-third, three at the junction of the middle and outer thirds, and one in the outer third.

CLINICAL MANIFESTATIONS OF NON-UNION

In fractures of the middle third of the clavicle, the shoulder is dropped forward, downward, and inward. If the fracture is located in the outer third, the deformity is minimum or absent. Nineteen of these twenty ununited fractures were in or near the middle third and there was some downward, forward, and inward displacement of the shoulder. In one fracture located in the outer third of the clavicle, there was no deformity at all. Fifteen patients had slight or moderate pain at the fracture site, radiating up to the neck with motion of the arm or when they were carrying objects. Three patients had pain at the fracture site radiating down the forearm and hand. Two patients had no pain at all.

Thirteen patients had no limitation of shoulder motion; six had slight restriction; and one had severe limitation related to adhesive capsulitis.

TABLE I *(Continued)*

DATA ON FIVE UNTREATED UNUNITED FRACTURES OF THE CLAVICLE

Duration of Non-union	Symptoms When Seen for Non-union	Length of Follow-up (*Years*)	Symptoms at Time of This Study
4½ mos.	Pain at the fracture site; total paralysis of the brachial plexus	10	Slight pain persists at the fracture site; the right upper extremity is almost functionless
11 mos.	Slight pain at the fracture site and in the neck; paralysis of brachial plexus, C_5, C_6	4	Pain in the neck and at the fracture site present when the patient lifts or carries objects with the involved extremity
10 mos.	Slight pain at the fracture site	5	Occasional pain at the fracture site
2 yrs.	Slight pain at the fracture site and in the neck when carrying loaded shopping bags or lifting relatively heavy objects	8	Slight pain at the fracture site and in the neck when carrying or lifting heavy objects
9 mos.	Pain at the fracture site; weakness of the small muscles of the hand	7½	Weakness of the small muscles of the hand not present; no symptoms

ASSOCIATED LESIONS

In two patients there was injury to the brachial plexus at the time of the fracture (Cases 16 and 17). Five other patients had some evidence of irritation of the brachial plexus, including weak muscles of the hand (Cases 4, 8, and 20) and hypesthesia and paresthesia in the distribution of the ulnar nerve (Cases 4 and 19).

There were no vascular complications among our cases, although pressure on the subclavian vein and contusion of the subclavian artery have been reported [6,7].

TREATMENT OF NON-UNION

The indications for operating on the fifteen patients who received surgical treatment in this series were: deformity and pain in eleven; deformity, pain, and weakness of the small muscles of the hand in two; deformity, pain, paresthesia, and hypesthesia in the ulnar-nerve distribution in one; and deformity alone in one.

RESULTS

In eight of the fifteen cases, an intramedullary Kirschner wire was not employed for fixation (Cases 7, 8, 9, 11, 12, 13, 14, and 15). In these instances, various types of grafts were used, with fixation accomplished by screws alone, screws and plates, and loops of wire, catgut, or kangaroo tendon (Table II). In all instances except two, external immobilization was continued for only four weeks. Only two of these eight fractures (Cases 7 and 11) united, and these had external immobilization for eight weeks. The reasons for failure appear to have been inadequate internal fixation, poor quality of the bone used for grafting, and insufficient immobilization after operation.

TABLE II

DATA ON FIFTEEN TREATED UNUNITED FRACTURES OF THE CLAVICLE

Case	Age (*Yrs.*)	Sex	Side	Occupation	Cause of Lesion	Original Displacement and Location	Initial Treatment	Duration	Symptoms	Finding at Operation	Method of Reconstruction	Type of Immobilization	Length of Follow-up (*Years*)	RESULTS	
														Anatomical	Functional
1	42	F	R	Housewife	Automobile accident	Marked overriding, mid-third	Figure-of-8 bandage, 4½ mos.	4½ mos.	Slight restriction of motion of shoulder; pain at fracture site	Overriding of fragments with 1 inch of separation; fractured ends very sclerotic	Iliac graft, cancellous bone; 2 screws, intramedullary Kirschner wire	2 wks., airplane splint; 10 wks., spica cast	3	United	Resumed original occupation; pain at fracture site and restriction of shoulder motion disappeared
2	18	F	L	Secretary	Congenital	Oblique, mid-third	None	18 yrs.	Pain in neck and at fracture site when carrying loaded shopping bag or other objects	Atrophic ends; large bone defect filled with fibrous tissue and yellow fluid	Same	Spica cast, 3½ mos.	4	United	Resumed original occupation; pain at fracture site and in neck ceased; able to carry loaded shopping bags
3	52	F	R	Housewife	Automobile accident	Comminuted fracture, mid-third	Figure-of-8 cast, 6 wks.	4 mos.	Slight restriction of motion of shoulder; pain in neck and at fracture site	Bone defect filled with fibrous tissue	Same	Spica cast, 8 wks.; sling, 4 wks.	3	United	Resumed original occupation; no pain at fracture site or in neck; very slight hypesthesia, right chest wall
4	22	M	R	Clerk	Football accident	Marked overriding, mid-third	Open reduction twice; wire loop	2 yrs.	Slight restriction of motion of shoulder; pain in neck and fracture site; hypesthesia in ulnar distribution; weakness of small muscles of hand	Gap between the fractured ends filled with fibrous tissue	Same	Spica cast, 4 wks.; sling, 8 wks.	3¾	United	Advised not to lift heavy objects; resumed clerical work; preoperative symptoms disappeared
5	4	F	R	Schoolgirl	Congenital	Unknown; junction of middle and outer thirds	None	4 yrs.	Slight pain at fracture site	Medullary canal obliterated; sclerotic ends; overriding of the fragments	Tibial autogenous onlay graft; screws, intramedullary Kirschner wire	Figure-of-8 cast, 2½ mos.	14	United	No symptoms; takes part in sports
6	37	M	L	Teacher	Bicycle accident	Overriding, mid-third	Figure-of-8 bandage, 6 wks.	6 mos.	Slight limitation of motion of shoulder; pain	Overriding of fragments with gap of about ¾ of an inch filled with fibrous tissue	Same	Figure-of-8 cast, 6½ wks.; at night, 2 wks.	8½	United	No limitation of shoulder motion and no painful symptoms; returned to original job
7	6	M	R	Schoolboy	Congenital	Unknown; mid-third	None	6 yrs.	None	Overriding of the fragments; atrophic ends connected with fibrous tissue	Onlay tibial autogenous graft; 4 screws	Figure-of-8 cast for 2½ mos.; figure-of-8 bandage, 2 wks.	10	United	No symptoms; takes part in sports

8	35	M	R	Painter	Automobile accident	Marked overriding of the fragments, mid-third	Sling for 3 wks.; intermediate treatment *	10 mos.	Pain in neck and arm on moving; weakness of small muscles of the hand	Bone defect; sclerotic ends with fibrous tissue between	Plate, screws; onlay tibial graft; clavicle excised because of pain at fracture site and neck and weakness of whole arm	Figure-of-8 cast, 4 wks.	18	Not united	Weakness of whole arm persists; slight pain in neck; unable to lift or carry relatively heavy objects
9	33	M	L	Clerk	Automobile accident	Overriding, mid-third	None	4 yrs!	Mild pain	Overriding; fibrous tissue interposed between sclerotic ends	Slot tibial cancellous-bone graft	Figure-of-8 cast, 4 wks.	20	Not united	Resumed original occupation; moderate deformity and slight pain at fracture site; cannot lift heavy objects
10	64	M	L	Salesman	Fall out of bed	Overriding, mid-third	Figure-of-8 cast, 4 wks.	13 mos.	Slight limitation of motion of shoulder; pain in neck and at fracture site	Loose fragment removed; bone defect filled with fibrous tissue	Iliac cancellous bone; intramedullary Kirschner wire	Figure-of-8 cast, 2 wks.	10	United	Resumed original occupation; plays golf; no symptoms
11	8	M	R	Schoolboy	Congenital	Unknown; mid-third	None	7½ yrs.	Pain in neck and at fracture site on motion of arm	Bone defect, ¾ of an inch, with fibrous tissue containing yellow fluid interposed between fractured ends	Autogenous rib graft; dual graft; loop of wire	Figure-of-8 cast, 8 wks.	3½	United	No symptoms; takes part in sports
12	12	M	R	Schoolboy	Congenital	Unknown; junction of middle and outer thirds	None	11½ yrs.	Slight pain at fracture site and in neck	Cartilaginous tissue bridging the fractured atrophic ends	Bone graft from resected ends; wire loop	Figure-of-8 cast, 4 wks.	3	Not united	No symptoms; abstains from throwing soft ball or taking part in contact sports because of pain in fracture site
13	20	F	R	Housewife	Fall	Overriding, mid-third	None	6 mos	Slight pain	Atrophic ends with fibrous tissue interposed	Bone graft from resected ends; kangaroo tendon	Figure-of-8 bandage, 4 wks.	20	Not united	Pain at fracure site when carrying loaded shopping bags; slight deformity of involved site
14	7	M	R	Schoolboy	Fall at age of 3 yrs.; ? of congenital origin	Overriding, mid-third	2 wks. after fall, figure-of-8 bandage for 4 wks.	4 yrs.	Slight pain	Overriding of the fragments; with fibrous tissue interposed	Bone graft from resected ends; catgut	Spica cast, 5 wks.	3	Not united	Painful symptoms when participating in sports
15	59	F	L	Teacher	Fall after epileptic attack	Overriding, junction of middle and outer thirds	Sling, 3 wks.	1½ yrs.	Pain at fracture site and in neck; slight limitation of motion of shoulder	Overriding; atrophic ends; fibrous tissue was interposed between them	Bone graft from resected ends; plate, 4 screws	Figure-of-8 cast, 4 wks.	16	Not united	Does housework but unable to lift or carry relatively heavy objects; slight deformity

* Failure of union after two open reductions.

Despite failure to achieve union, among the six failures, two of these patients resumed their original occupations, that of teacher and clerk. One is a housewife, and has some difficulties because of pain when carrying loaded shopping bags. Two patients were children who are still going to high school; they have moderate pain when engaged in athletics, such as throwing a soft ball or participating in contact sports. Therefore, they abstain from these sports. In the remaining patient of this group (Case 8), the whole clavicle was excised, mostly because of persistent pain at the fracture site and in the neck. This patient continues to have mild discomfort in the operative site and neck, and weakness of the whole arm. He is unable to carry or lift relatively heavy objects, but he has not had to change his occupation, since he is a painter.

In the remaining seven cases, intramedullary fixation with a Kirschner wire was used in combination with various types of onlay grafts and from two to three and one-half months of immobilization in a shoulder spica or plaster figure-of-eight bandage. All the fractures so treated showed roentgenographic evidence of solid fusion at the time when immobilization was discontinued.

Final evaluation of the results in the nine patients in whom union was obtained revealed that eight had gone back to their original occupations, whereas one had taken a lighter job on the advice of his surgeon. Of the six who had had some restriction of shoulder motion before operation, all had regained a normal range of motion. Pain at the fracture site and in the neck, which had been present before operation in eight of these patients, had been relieved. The paresthesia and hypesthesia over the distribution of the ulnar nerve and the weakness of the muscles of the hand had gradually disappeared after operation in the five patients with these

FIG. 2-A

Figs. 2-A through 2-C: Case 2 (G.F.).
Fig. 2-A: Ununited fracture of the right clavicle; there was a question of congenital origin. There were painful symptoms.

symptoms. Hypesthesia in one patient developed over the upper chest wall after operation, probably as the result of section of the mid-clavicular branch of the superficial cervical plexus.

REPAIR OF PSEUDARTHROSIS

If repair of a pseudarthrosis in the clavicle is indicated, the following technique is recommended:

The operation is performed under general anesthesia, with the patient supine and a sand bag under the involved shoulder. A curved incision is made over the clavicular region, so placed that the lowest point of the incision overlies the second

rib. After division of the platysma, it and its overlying tissues are reflected upward, and the pseudarthrosis is exposed. The periosteum is incised along the anterior border of both fragments and elevated for a short distance. The fibrous tissue in the pseudarthrosis is excised; any sclerotic bone is resected until bleeding bone is seen. Then the medullary cavity is opened with a small drill, and the superior surface of each fragment is made flat, with an osteotome, as a bed for the graft. A threaded Kirschner wire is introduced into the lateral fragment and advanced until it penetrates the skin in the region of the acromion. It is then inserted into the medial fragment in a retrograde fashion. An iliac-bone graft consisting of the outer cortex is applied to the previously prepared upper surface of the clavicle and is fixed with two screws, one in each clavicular fragment (Figs. 2-A, 2-B, and 2-C). Chips of cancellous iliac bone are packed into the defect between the bone ends, and the edges of the onlay bone graft are shaped so that no projection can be felt under the skin.

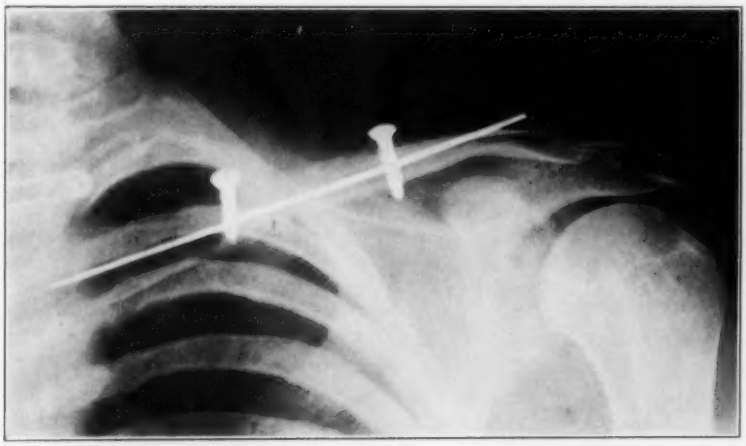

FIG. 2-B

Roentgenogram made at three and one-half months after operation.

FIG. 2-C

Eighteen months after operation. The wire and screws were removed; there was solid union.

DISCUSSION

The findings in this study suggest that non-union of fractures of the clavicle may be prevented if any appreciable displacement of the fragments is reduced by manipulation (under anesthesia, if need be), if immobilization is continued until union is complete, and if inadequate internal fixation is avoided when open reduction is employed. Open reduction may be indicated if there is a gap of one-half inch or more between the fracture ends and manipulation fails to reduce this displacement. Intramedullary fixation should always be used if open reduction is performed.

With an established non-union, the indications for surgical treatment are disability and pain or neurological and vascular complications rather than deformity. After such a fracture, if pain persists or if there are signs of pressure on the subclavian vein or artery or the brachial plexus, and the fracture occupies the middle third of the clavicle, intramedullary fixation and bone graft are indicated, particularly when the patient is an adolescent or young adult. Under these circumstances, open reduction will prevent the complications of non-union, and asymmetry and weakness of the shoulder may be avoided. With fractures of the outer third of the clavicle and persistent painful symptoms, excision of the outer fragment should be sufficient.

SUMMARY AND CONCLUSIONS

Twenty ununited fractures of the clavicle have been reviewed. The factors predisposing to pseudarthrosis were severe trauma with persistent gross displacement of the fragments, primary open reduction with inadequate internal fixation, and insufficient external fixation. Fractures of the middle third of the clavicle may be more prone to non-union. If painful symptoms persist in the presence of non-union, intramedullary fixation and an onlay bone graft are indicated. An onlay iliac-bone graft fixed with screws combined with cancellous iliac bone packed between the ends would appear to give the best results. A spica or figure-of-eight plaster encasement should be used as external immobilization.

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A Modified Half-Ring Splint and Combined Foot Support and Exerciser*

BY FREDERIC W. ILFELD, M.D., BEVERLY HILLS, CALIFORNIA

The half-ring Thomas splint, modified to give increased room and comfort in the groin, and a special foot piece that provides active resistance exercise as well as support for the foot have been used successfully for the past eight years.

The proximal three to five inches of the inner rod of the conventional half-ring splint are replaced by an adjustable right-angle offset (Fig. 1). This offset is

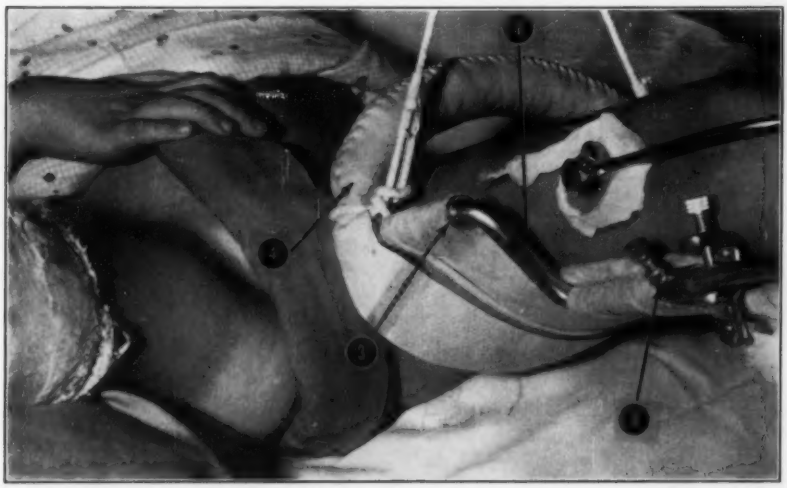

FIG. 1

Adjustable offset for a half-ring splint.

1 = right-angled offset; 2 = distal sleeve joint with sleeve and set screw on the distal limb of the offset; 3 = the proximal sleeve joint, which is free to rotate since it is held only by a pin that fits into a circular groove in the proximal limb of the offset (not visible); and 4 = hinged half ring. The proximal end of a Pearson attachment on the splint can be seen just distal to the lower sleeve.

attached to the splint by two sleeve joints. The proximal sleeve, which is attached to the inner rod of the splint about three and one-half inches distal to the hinged half ring, receives the proximal end of the offset. The offset is held in the sleeve by a pin. This pin is fixed to the sleeve and projects into a groove encircling the proximal end of the offset. The pivot joint formed by this arrangement, in combination with the hinged half ring, permits adjustment of the splint for use on either limb. This pivot also permits some adjustment of the position of the offset to provide greater or less clearance of the groin.

The sleeve of the distal joint is about three inches in length; it is located on the offset and is fitted with a set screw. The distal portion of the inner rod of the splint fits into this sleeve and has flattened areas on it to give the set screw a firm grip and thus prevent sliding or rotation of the offset. This distal sleeve joint

* Presented as an exhibit at The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 24 through 29, 1959.

with its set screw makes it possible to adjust the rotation and length of the inner rod of the splint, thus preventing impingement of the brace against the groin. The set screw may be adjusted by an Allen wrench or pliers.

When the splint is used, the hinged half ring is placed on top of the limb. This eliminates the discomfort sometimes caused by the presence of the ring beneath the limb. If the limb is in traction, countertraction is obtained by elevating the foot of the bed.

The foot support (Fig. 2) consists of a padded metal plate attached to one-half of a screen-door hinge that has an adjustable spring. The other half of the hinge is attached to the inner and outer rods of the splint or to the side bars of a Pearson attachment, if the Pearson attachment is used. With this device, the foot is supported perpendicular to the splint, but plantar flexion against the resistance of the spring is possible. The foot piece is attached to the side bars of the splint or of a Pearson attachment by means of lateral extensions. Clamping devices that resemble small C-clamps are attached to the lateral extension. With

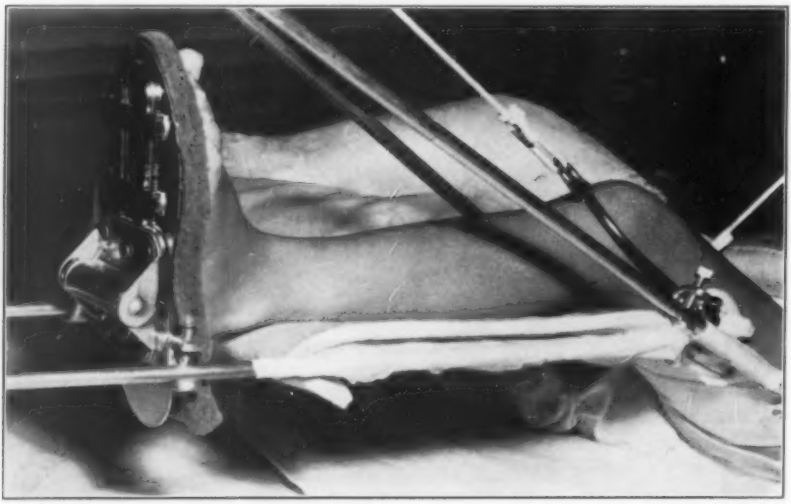

FIG. 2

The foot support with adjustable screen-door hinge with spring, as described in the text.

these clamps the foot piece can be attached firmly anywhere on the splint. To accommodate for different widths of the splint or Pearson attachment, the lateral extensions of the foot piece are attached to the hinge by rectangular sleeve joints that permit adjustment of the length of the lateral extensions. The Allen wrench and a rod used for adjusting the tension of the spring are stored on the back of the foot piece, out of reach of the patient, yet handy for the surgeon.

The foot and leg muscles are actively exercised by plantar flexion against the resistance of the screen-door hinge and spring. The patient instinctively uses the exerciser. The amount of resistance can be regulated as necessary by adjusting the tension of the spring. Active resistance of the foot maintains muscle tone and discourages thrombophlebitis.

Orthopaedic Payola*

BY HUGH SMITH, M.D., MEMPHIS, TENNESSEE

Perched on the Chickasaw bluffs above the Mississippi River at the apex of the Mississippi delta is a thriving community of half a million people—Memphis, Tennessee. I live there. It is not so commercial or so bustling as New York or Chicago; not so cosmopolitan as San Francisco or New Orleans; not so gay as Miami Beach. Its citizens have an average interest in the arts; it is the home of three universities, and it has an expanding medical center. In terms of millennia, its history is short. True, it is superimposed upon layer after layer of Indian civilizations. But it was only about 520 years ago that DeSoto arrived there, staying long enough to build boats and barges for his men to cross the river. The French and the Spanish built forts there. About 140 years ago a small colony sent there by Andrew Jackson established the first permanent settlement. Like the ancient Egyptian Memphis, it is a "place of good abode".

Five thousand years ago, the Egyptian Memphis was founded at the apex of the Nile delta. For 1,000 years it was the home of the Memphian Pharaohs, the beginning and the crest of ancient Egyptian civilization. It was a large city, a center of learning, of architecture, of engineering; its people were prosperous, peaceful, creative. Its rise to eminence, beginning about 2900 B.C., was materially influenced by Imhotep, the first physician of whom we know. Imhotep was not only a physician; he was a statesman, astronomer, priest, and architect, in every sense the prime minister of the Pharaoh Zoser. As an architect, he designed the step pyramid at Sakkarah, which supplied the basic pattern for a burst of architectural magnificence culminating in the great pyramids at El Gizeh. As a priest and physician, his wisdom became traditional. In death as in life he was sought by the sick and helpless; his tomb, not far from the pyramid he designed, became a shrine where wonderful cures were wrought. His fame grew from century to century; temples were dedicated to him, and he came at last to be regarded as divine, the Egyptian god of healing. Memphis remained the chief center of his worship, and generations of doctors were trained there.

Although this Egyptian society was to last at least three times as long as our Western society has existed so far, only one-fourth of its history was seminal and flourishing. Half was a weary epilogue. The decline began during the sixth dynasty (2424 B.C.): authority was whittled away; civil and religious rights went to whoever was strong enough to seize them; and the long decay brought with it scarcity, insecurity, and moral disintegration. Some troubled sage inscribed a tablet for us to read: "Come, my heart, that I may talk with thee, and thou mayest answer my words. Mayest thou explain to me what is happening all over the land." He could not explain the causes, or assign the responsibilities, but he did conduct a melancholy examination of signs and symptoms.

Here was the spawn of moral disintegration: bribery, tribute, plunder, corruption. In 1730 B.C., day and night, the streets and temples of Memphis thundered with horsemen, the conquering Hyksos, a Semitic tribe from Canaan. Darius I of Persia was the next conqueror, in the sixth century B.C. Though he reestablished Memphis as the medical center of its day, the internal energies of

* Presidential Address read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Miami Beach, Florida, January 10, 1961.

Egyptian society had been dissipated. The great tradition was no longer inspiring; it had become stifling. Gradually, the erosion of time and the vandalism of man transformed Memphis into shapeless ruins and rubbish among the sands and palm trees. One of its buildings alone, the temple of Ptah, had once measured a third of a mile in length and a quarter of a mile in breadth. Now, the city and its temples lay so utterly destroyed that even their location remained unknown for many centuries. The Song of the Harper sang, "I have heard the discourses of Imhotep and Hardedef. Where are their habitations now? Their walls are destroyed; their habitations are no more, as if they had never been."

This scene is dismal to contemplate; but as Santayana said, "He who ignores history must be prepared to repeat it." Can we correlate the history of ancient Memphis in Egypt with the present status and future of Memphis, Tennessee, and of the United States of America with its magnificent cities, its monuments to engineering, its art, its medicine? A Southern proverb is well worth remembering here: "While you are green, you are still growing, but when you are ripe you are next to rotten." What happened to ancient Egyptian society happened to Periclean Greece, where the ruins of Aesculapian temples still stand; it happened to Rome, whose proud Forum was trampled by the Goths, and Galen remembered only by rote. Is our own once lean and sinewy drive, our sharp sense of right and wrong, our courage against odds, our self-reliance, already fattened into the ripe stage that precedes the rotten? Is it fair to contrast the independent courage of Dr. Ephraim McDowell, performing the first ovariotomy on a kitchen table while an angry mob shouted outside, to our smug self-satisfaction in gleaming operating rooms, surrounded by the latest and most expensive gadgets, and by public admiration and awe?

By profession we are surgeons. By birthright and belief, we are citizens. What we are and do as citizens must inevitably affect what we are and do as surgeons; and as surgeons, citizens. Let us look quickly at the international and national scenes of which we are a part, and then more searchingly at our profession.

On the international scene, we hear some voices, once raised in affectionate admiration of our way of life, now shouting "Yankee go home!" Not all of these voices are uneducated. Our behavior abroad sets up a contrast between vulgar affluence on the one hand and ignorant poverty on the other. Our second-hand reputation tarnishes the image of justice. Our naive or temporizing alliances with flashy dictators, crooked promoters, and fly-by-nighters are unworthy of the statue and the statutes of liberty. Our optimism has become shallow and thin, lacking hard contact with the soil and the struggle for daily bread. We no longer know how to estimate or to cope with the ruthlessness of international communism. We do not know how to be good liars, but we have forgotten how to be men of truth.

At home, it is no longer fashionable to be self-reliant and self-supporting. We band together in all sorts of pressure groups, and urge conformity by statute. We all seem to want more and more "security". The Townsend plan and the "chicken in every pot" have been presented in new lingo; we tax the efficient to preserve the inefficient. Individualism is old-fashioned; only the state can bring about our millennium, in power, in transportation, in farming, in housing, in education, and in medical care.

In our personal lives, our tendency is to resist all these grand socialistic schemes, on principle, but to forget the principle also of our individual responsibilities. We loaf along on the notion of a middle-of-the-road morality. To our grandfathers, there was no such middle on moral issues. There was right; there

was wrong. But the dollar sign makes us uneasy, and there are the Joneses to keep up with, and many a dubious deal is entered into without any clear definition of its essential nature. Let us avoid the ugly words bribe, fraud, cheating, stealing, corruption. The word *payola* is the word to use: it is almost an affectionately slangy term for some of these deals. Is anyone really condemned for making a fast buck? Or is he secretly admired for knowing how to stay within the law and yet "get ahead"? Is payola a shame, or an excitement?

Examples of payola are legion. The most famous, perhaps, is this: on a rigged quiz show, the participant makes $129,000, lies to a grand jury, says he is sorry, is praised by congressmen for his frankness, and keeps the money. Far more prevalent, and less attention-getting, are the padded expense accounts, the cheating income-tax returns, the vicuña coats and the deepfreezes, right on down to the butcher with his thumb on the scales.

This brings us to the point: orthopaedic payola. You may cringe at this combination of terms, but there *is* orthopaedic payola, in many forms. It may be subdivided into two general classes, the benign and the malignant. Is this too far from the ruined temples of Egypt? On our one-dollar bills is the image of a pyramid, and we shall do well to remember it and the searching eye at its peak. While payola in any form seems repugnant to us, we do not always recognize it. The benign forms are more prevalent than the malignant, but both contribute to the deterioration not only of our personal integrity, but in consequence, the integrity of our profession and our country. Let us see whether as orthopaedic surgeons we are still green and growing, or dangerously ripe.

First as to benign orthopaedic payola. Those who practice this form of selfishness are usually not even aware of it. They have no financial reward; it is usually attention they are after. Their behavior ranges from the laughable to the painful. At times it may be merely a matter of letting a mean and nasty disposition go unchecked. Perhaps it is a streak of jealousy or vindictiveness. Perhaps it is ill-timed showmanship. At best, it wastes our time and energy; at worst, it violates all the reasons why we gather in such a convention as this to share our knowledge and excitement. To see it in action, let us take a close, satirical look at one form in which it displays itself. I call it the art of derogatory discussion.

Implicit in the creed of the derogatory discussor is that he must alienate the audience, at least by boredom or bombast, and that he must never under any circumstances say anything useful. Since these objectives can seldom be accomplished in three minutes, he must be well versed in the techniques of outsmarting the chairman's time schedule. There are dozens of methods of derogation, and you must select one to suit your own talent and personality.

One is the historical. This is a good way to conceal any embarrassment about being in over your head and uninformed. A couple of outdated orthopaedic texts will supply ample material from Hippocrates to 1934. When time is called, merely regret your lack of time to present the truly scientific part of your discussion. Suggest, in closing, that Hippocrates understood the very principles enumerated by the essayist, and recall with grace that a similar procedure was reported by your grandfather in an obscure journal from Civil War days: he performed it at Shiloh with only a jigger of applejack as anesthesia.

That is a suave and insidious method of wasting time. A more dazzling, crackling way is the statistical. If the essayist has only twenty-seven cases, and one of these has a follow-up of less than five years, you have it made. In rapid succession, show eight "O-my-God" slides (twenty-two lines of figures across and fourteen down, in microtype). On Slide 1, call attention to a figure in the upper left-hand corner; on Slide 2, in the lower right-hand corner; and on Slide 3,

in the center. This is known as scientific tick-tack-toe, and will at least keep *you* from being bored. For copy, photograph the last eight stock-exchange reports, but keep the print small enough so that it cannot be read at fifty feet even with Zeiss binoculars. Use a machine-gun style; let the audience hear only occasional figures, such as 420 or 670. These, of course, are the latest quotations on IBM or Rohm and Hass, but who will be the wiser? Close with a stream of technicalities about the t-values and the mean standard deviation, and few will be able to say how little you have said.

If you have a flair for the dramatic, you can make a real production of your discussion. You must practice it assiduously in advance, with a stop watch. Build up in a crescendo of gesture and voice which promises a tremendous climax to come (it never does). This helps to evade the time limit more easily. Before your scheduled time arrives, make it a point to be seated in the last-row center of the audience. Lift your heavily loaded brief case high, and slowly work your way to the aisle. Politely acknowledge that you are stepping on everybody's feet. Move slowly toward the podium; stop on your way to shake hands with at least two strangers and, of course, with the essayist. Ask him in a stage whisper if he has really checked the figures on page twenty-three, and wait for his reply. Once on stage, remove a bulky folder from your brief case. Conduct a careful search for the proper page (it should be in the middle), being sure to riffle the sheets into the microphone. Properly done, this can be Wagnerian. Clear your throat, also into the microphone; swallow some water; clean your glasses; then proceed with your first derogatory remark. Just as the anxious chairman is about to cut you off, announce that you have prepared a movie. Then he has no earthly way to stop you (after all, you have slipped the operator five bucks, and the volume is turned up fifteen decibels above normal). A good sound track, thoroughly laced with music, will compensate for lack of subject matter. At last, with a 3-B fanfare, smile innocently, and thank the chairman and the audience. Ignore the speaker.

Some may regret that these and other techniques are not more popular; they keep us from having to think, and continued practice of them might result in some radical changes in our system of programming. But there are a difficult few who will not learn them, thank God, and for this reason we shall probably continue to have conventions and to come away with new ideas. The time-wasters, meanwhile, have achieved their own small share of benign payola: they have had the spotlight, their names come out in print, and they can subtract some of their expenses from their annual income-tax report.

But we are beset by other kinds of orthopaedic payola, far more virulent and damaging. I call these forms malignant. They not only eat away at our time and energy, they undermine our very integrity. Few of us practice them, and many of us are hardly aware of them. But they are real, and to sharpen awareness, again let us take a satirical magnification of how they look and work.

Malignant payola always operates within the terms of middle-of-the-road morality; that is why it is so dangerous. You never risk ostracism by your colleagues, or a loss of hospital privileges, or a frown from your medical society. You are discreet in your pursuit of the fast buck. You conveniently forget the Hippocratic oath, in favor of a hypocritic one. After all, everybody else is getting theirs, so you are quite within your middle-of-the-road rights to get yours. Here are some ways to do it.

First, charge all the market will bear. You can always come down, if there is too much fuss. Just be careful not to price yourself out of the market. If your patient has good insurance, charge all it will pay, and then up the ante a little. Insurance companies have lots of money. Why bother if premiums go up, or if inflation spirals?

Another device is this. Does your patient have no cash, but a little property? Then send him to his bank to borrow the money, and sign his note for him. The bank can worry about being the bad-debt collector and foreclosing on the property, and at worst, you would only have to refund the money. Of course it is better to insist on cash in advance: money talks, and cash in advance is sound fiscal policy.

The best gimmick is the disability estimate, the expert-witness racket. "Whose bread I eat, his songs I sing." Work it both ways to the center. Do you love the plaintiff and his woes? Does he need a poultice of greenbacks? Then increase your estimate for him: after all, this is not a science, it is a delicate matter of professional judgment, and the poor fellow says he has been through hell. Do you love the defending lawyer and his insurance company? They are good cash accounts. Then brush off the plaintiff and decrease the disability, and soon shysters will flood your office with clients. Very soon you can have a medicolegal gin mill going, and before long the lawyers should cut you in on a contingency basis for a third of the proceeds.

It goes without saying that your indications for surgery will not be conservative. Push the panic button on the most benign lesion. Fuse every aching back. Do lots of prophylactic meniscectomies. For a sprained neck, always use the lay term "whiplash": this can be made to sound terrifying. You can keep the patient in traction for two or three weeks, toss in a myelogram, a neck brace, and some dire neurological terms to justify a bill for two or three hundred dollars, and yet do very little work for it.

These are some of the myriad forms of orthopaedic payola. Are they rare? We hope so, but even one such shady middle-of-the-road deal can poison the atmosphere of a whole country.

My idea of genuine orthopaedic payola is vastly different from any of those that I have presented. I am going to wrench that word *payola* away from its popular meaning of the fast buck, the smart deal, and give it an entirely different connotation: the legitimate reward of honest effort. It cannot come from the shoddy, the lazy, the dishonest, or the selfish. It comes from you and your own hearts. It is the successful consummation of your dreams and ambitions. It is the realization that orthopaedics is not a business, it is a calling. This kind of payola can be a magnificent pay-off, not to be measured in dollars and cents. Life becomes infinitely enriched when you know that your greatest satisfaction and reward is your work; that it is honorable, skillful, constructive, and valuable.

The satisfactions of genuine orthopaedic payola can range from the daily rewards of patient skill to the rare heights of vision; from lonely night reading to a gathering like this. You find it in the pleasant relief that comes with having successfully sweated out a difficult operation, or having saved a critically injured patient, or reconstructed a severely injured extremity. It may come in the joy of hearing a grateful patient just say "Thank you."

At any level it is satisfying beyond any public praise or reward. The busy one-man surgeon who serves a large community is too hard-pressed by his immediate responsibilities to shine as a scholar. He may not have the time to read more than the current issue of *The Journal of Bone and Joint Surgery*, if that; he may not have the money to buy the latest equipment or the fleet of technicians that lessen his load; he may have little means of organization, and his office is snowed with paper work. But his skill increases, his patients are grateful, his heart is warm with his life. Such men by the hundred make the base of our pyramid. Without them, our profession would crumble.

On up the scale are the men who are so fortunately situated that in addition

to their daily practice, they can do the footwork on our committees; the men who write and edit our journals and give our instructional courses; the men responsible for bringing us together in print or in a meeting, to advance our knowledge, enlarge our professional horizons, and sharpen our insight. Some of them teach; some of them engage in research, and therefore have the satisfaction of responsive students and new knowledge. Their work is essential, and no payola is so invisible as this, or so important.

At the top of the pyramid are a rare few, the men of extraordinary vision as well as of skill, of mind as well as of heart, whom fortune has placed in positions of great power, but who know how to use that power with the greatest humility. They are responsible for the growth of our schools and our research programs; their insight changes a whole generation of scholarship and practice; they are not only surgeons of the first order, but are prodigious readers and writers. Their enormous patient power of discipline and concentration makes the most of our lives seem a little foolish, a little wasteful. They truly understand the meaning of orthopaedic payola, and that is the payola to which we are dedicated. With that reward in sight, our hospitals and temples will last a long, long time. Our pyramid will not crumble; we shall keep orthopaedics green and flourishing.

Proceedings

FORUM ON FUNDAMENTAL PROBLEMS IN ORTHOPAEDIC SURGERY

MEETING OF THE AMERICAN COLLEGE OF SURGEONS

October 10, 1960

AS PREPARED BY CRAWFORD J. CAMPBELL, M.D., ALBANY, NEW YORK

The Forty-sixth Annual Clinical Congress of the American College of Surgeons was held in San Francisco, California, on October 10, 1960. Summaries of the papers presented at the Orthopaedic Section of the Forum on Fundamental Problems follow:

The Fate of Surgically Created Osteochondral Fractures in Adult and Young Dogs. DR. ROBERT W. BAILEY [1] and DR. DAN W. HABEL studied the femoral condyles of both immature and mature mongrel dogs from which wedges of articular cartilage and underlying subchondral bone were removed and then reinserted. In the adult dogs there was rapid union of the bone portion of the graft to its bed. Although the articular cartilage did not show degeneration, either grossly or by metachromatic staining, there was no evidence of repair of clefts formed between the cartilage of the fragment and the adjacent cartilage. In the puppies, the clefts along the articular surface showed good healing with cartilage. Even if the fragment was dislodged, there was a tendency toward healing of the defects with cartilage.

Experimentally Produced Changes in the Rabbit Resembling Legg-Calvé-Perthes Disease. DR. R. K. GREENLAW [2], DR. DAVID S. KAHN, and DR. J. GORDON PETRIE were able to produce aseptic necrosis of the femoral head in rabbits by extracapsular ligation and division of the medial circumflex femoral artery. The femoral heads of all specimens showed flattening and distortion comparable to that seen in Legg-Calvé-Perthes disease; studies by microangiography confirmed the epiphyseal ischemia.

Energy Expenditure during Early and Late Convalescence from Multiple Fractures. DR. HARVEY A. ZAREM [3], DR. JOHN M. KINNEY, and SHEILA NICHOLS used a modification of indirect calorimetry to measure the daily energy expenditure and utilization of food in a patient recovering from multiple fractures. The data acquired by analyzing hourly samples of expired air for carbon dioxide and oxygen and the urinary nitrogen excretion indicated the proportion of calories arising from fat, carbohydrate, and protein.

The daily expenditure of calories was higher than would be expected of a bedridden patient without trauma. As convalescence progressed, the daily expenditure reached 1,550 calories by the final week of a total of fourteen weeks. By the fourth week a positive nitrogen balance associated with weight gain was noticed. The patient received testosterone for two fourteen-day periods. After the end of the second period he lost 3.2 kilograms of body weight; this was attributed to the withdrawal of testosterone.

Polyurethane Foam (Ostamer): Its Use in Experimental Animals and in the Investigation of Tissue Reactions. DR. R. K. MACOOMB [4], DR. C. HOLLENBERG, and DR. W. ZINGG evaluated the use of polyurethane foam in experimental fractures of the long bones of sheep, dogs, and calves, and its effect on callus formation in the healing of fractures in rats.

In the experiments on the large animals all the procedures using ostamer alone or in combination with intramedullary pins failed, except in one instance. Where Sherman bone plates or transfixing screws were used in conjunction with the ostamer there were four successes and three failures. There were many infections. At post-mortem examination, the ostamer plug was freely movable with no evident bonding to bone.

Histological examination of thirty subcutaneous implants revealed an initial acute inflammatory reaction followed by a low-grade inflammatory reaction and eventual envelopment by scar tissue. Histological sections of forty-two fracture-site implants showed that callus formation is not

1. University of Michigan Medical Center, Ann Arbor, Michigan.
2. Department of Surgery, McGill University, Montreal, Quebec, Canada.
3. Department of Surgery, Harvard Medical School, Boston, Massachusetts.
4. Department of Surgery, University of Manitoba, Winnipeg, Manitoba, Canada.

affected by its proximity to ostamer, but is delayed because of the space-filling nature of the material. The study failed to show evidence of osteoblastic activity within the lacunae of ostamer, and fibrous-tissue invasion of the implant was limited to only the marginal lacunae.

Experiments on Pyogenic Arthritis. Dr. Bernie P. Davis [5] and Dr. John Ring studied the effects of various antibiotics used to control septic arthritis in the knees of rabbits. Disease was produced by injecting .1 cubic centimeter of saline suspension of penicillin-resistant, hemolytic, coagulase-positive *Staphylococcus aureus*, containing 100 million organisms per cubic centimeter of solution. Treatment of rabbits was started three to seven days after injection, when swelling was first noted. The rabbits treated with daily injections of 500 milligrams of bacitracin or 100,000 units of penicillin were not benefited. In twenty-five rabbits treated with either 50 to 100 milligrams of albamycin or neomycin, 92 per cent of the joints were sterilized and 72 per cent of the rabbits had preserved or useful joints.

The Treatment of Penicillin-Resistant *Staphylococcus aureus* Joint Infections with Intra-articular Broad-Spectrum Antibiotics. Dr. Charles J. Frankel [6], Dr. Curtis V. Spear, Dr. J. Robin Hicks, and Dr. Y. T. Hsu studied the effect of varying daily doses of chloromycetin succinate, erythromycin, novobiocin, and kanamycin on experimentally produced joint infections caused by penicillin-resistant, hemolytic, coagulase-positive *Staphylococcus aureus*.

Erythromycin caused more inflammatory change when injected into uninfected joints and was less effective in treating the infected joints. The authors concluded that the intra-articular use of the proper amounts of chloromycin, novobiocin, kanamycin, or bacitracin with aspiration and saline irrigation is indicated.

Fat Embolism in the Rat. Dr. Kenneth S. Morton [7] and Marie J. Kendall attempted to classify the pathogenesis of fat embolism in experiments on adult rats.

An analysis revealed that there was an average of thirty-six milligrams of fat in each femur and 39.5 milligrams in each tibia.

In twenty-six animals intravenous injections of one-sixth to four times the amount of fat found in the femur showed that even in the smallest amounts the lungs were heavily loaded with emboli, some reaching the kidney. All animals survived. Using the grading of Gkas (1 to 4), the authors found a pulmonary fat embolism averaging Grade 2.3 in twenty-six animals with hind-limb fractures. If the animals were held at 100 degrees Fahrenheit one-half of an hour before and after fracture, the grade was 2.7, with heavy loading in the lungs in occasional animals. The vasodilator drug, largactil, did not increase the grade of embolism. The authors inferred that the mechanical theory of pathogenesis of fat embolism is at least a plausible explanation in the clinical syndrome.

A Method for Obtaining Ionic Gradients Across Living Bone. Dr. Melvin Post [8], Dr. Jorge O. Galante, and Dr. William C. Shoemaker studied the arterial and venous systems in the femur of dogs by injecting radiopaque substances; they believe that the nutrient artery and the venous efflux systems are constant and the vessels can be cannulated. Eight to 10 per cent of injected chromate isotope (C 51-labeled red blood cells) was recovered from the lower venous efflux system whether the isotope was injected by way of the nutrient artery or directly into the medullary canal. After the injection of varying amounts of hydrochloric acid, blood collected from the lower venous efflux system showed a relatively high concentration of sodium, as compared with simultaneous samples obtained from the carotid artery. There was no significant change in the potassium concentration. The authors believe that there may be a reciprocal exchange in bone between sodium and hydrogen ions in response to a sudden change in the acid-base balance.

Studies on the Pathogenesis of Collagen-Tissue Changes in Alcaptonuria. Dr. Robert Austin Milch [9] noted that swelling of collagen (obtained from n-acetylated, limed, bovine-hide powder) was produced by unoxidized (HGA) and autoxidized (HGA-OP) solutions of homogentisic acid, by structural carboxylic-acid analogues of unoxidized homogentisic acid, and by buffer solutions over a wide pH range.

5. University of Buffalo, Buffalo General Hospital, Buffalo, New York.
6. University of Virginia Hospital, Charlottesville, Virginia.
7. Department of Surgery, University of British Columbia, Vancouver, British Columbia, Canada.
8. Michael Reese Hospital and Medical Center, Chicago, Illinois.
9. The Johns Hopkins University School of Medicine, Baltimore, Maryland.

Swelling of isoelectric collagen was strongly pH-dependent and reversible in all studies except those employing autoxidized solutions of homogentisic acid. In these, the degree of swelling was unaffected by the pH of the liquid phase and related significantly to the degree of polymerization of autoxidized solutions of homogentisic acid. This suggests that autoxidized solutions of homogentisic acid can tan collagen by forming interchain cross-links with adjacent polypeptide chains of collagen macromolecules. This was further demonstrated in adsorption studies performed by the Tiselius-Claesson frontal analysis chromatographic technique, and on electromicrographs in which electron-dense amorphous deposits, presumably of autoxidized solutions of homogentisic acid, were found to be localized exclusively on collagen fibrils and fibers. This would suggest that the autoxidized solution of homogentisic acid interacts with connective tissue by way of the collagen component.

The Vasodilatory Response to Skeletal Trauma. Dr. James B. Wray [10] and Dr. Merrill P. Spencer studied the blood flow in the femoral vascular bed after fracture of the tibia in twelve male mongrel dogs anesthetized with nembutal. The carotid artery and femoral artery of the other limb were used as controls.

The authors showed that there is a marked vasodilatory response on the side of the fracture, as measured by an increase in the blood flow through the limb. Vasoconstriction was noticed in the opposite limb.

Perimetric Analysis of Scoliosis: A Three-Dimensional Concept. Dr. J. William Hillman [11] revived a method, advocated by Meisenbach in 1911, of perimetric measurement and analysis of the deformity of the chest. The apparatus used in this method has many metallic rods passing through a metallic ring in such a manner that their tips conform to the contour measured.

The author believed that a reduction in cross-sectional area, in general, is an ominous sign. A consistent perimetric pattern is considerable assurance that no additional rotation is taking place in the thoracic vertebrae. Additional rib deformities, even after spine fusion, which often cause a worsening of cosmetic appearance, are apparent in this measurement. This method was presented as an adjunct to other measurements in the analysis of scoliosis.

Scoliosis: The Effect of Unilateral Resection of the Paraspinal Musculature in Normal and Bipedal Rats. Dr. James W. Dinsmore [12] did a superficial and deep muscle-mass resection on the left side extending from the sixth thoracic vertebra through the thirteenth thoracic vertebra in rats, approximately three weeks of age, and weighing less than fifty grams. He noted that in the bipedal rats there consistently developed a moderate scoliosis in the thoracic regions, with a convexity toward the side opposite the muscle resection. The quadripedal rats showed more variation, but essentially a more severe scoliosis in the same area and side. The controls showed little or no curvature. An exploration of the operative site at autopsy in some of the animals revealed a marked scar-tissue formation in the area of muscle resection.

The author concluded that a traction scoliosis and not a paralytic scoliosis had developed.

10. Bowman Gray School of Medicine, Wake Forest, North Carolina.
11. Vanderbilt University School of Medicine, Nashville, Tennessee.
12. University of Kansas Medical Center, Kansas City, Kansas.

THE JAPANESE SOCIETY FOR SURGERY OF THE HAND

Fourth Annual Meeting

As Prepared by Joseph H. Boyes, M.D., Los Angeles, California

The Fourth Annual Meeting of the Japanese Society for Surgery of the Hand was held in Niigata City, Japan, on September 30 and October 1, 1960, under the Presidency of Dr. S. Kono. The Guest Speaker was Dr. Joseph H. Boyes, Los Angeles, California. Prof. Kashiwagi, of Kobe University, was elected *President* for the coming year.

The Scientific Exhibits at the meeting were:

Histological Findings of Ruptured Free Tendon Grafts. Dr. T. Kotani and associates, Shiritsu University;

Splints for the Hand. Dr. N. Takagishi, Hiroshima Red Cross Hospital;

Treatment of Volkmann's Contracture. Dr. K. Tsuge and associates, Okayama University;

Operative Reconstruction of Thumb Opposition. Dr. K. Tsuge and associates, Okayama University;

An Investigation of Grasping Power. Dr. T. Egawa and associates, Osaka University;

Histochemical Study of Experimentally Ruptured Tendons. Dr. T. Hoshino, Wakayama University;

Experience with Artificial Tendon-Grafting in the Hand. Dr. S. Iwata and associates, Tohoku University;

Angiographic Investigations of Injured Fingers. Dr. S. Matsubayshi, Tokyo Labor Compensation Hospital.

The Audio-Visual Program, all in 16 mm. color, consisted of:

Principles of Treatment in Surgery of the Hand. Dr. T. Tajima and associates, Niigata University Research Group of Hand Surgery;

Elastic Splints for Routine Use in Surgery of the Hand. Dr. T. Tajima and associates, Niigata University Research Group of Hand Surgery;

An Investigation of the Function of Injured Hands. Dr. K. Hamazaki and Dr. H. Hasegawa, Kyushu University and Kyushu Labor Compensation Hospital;

Treatment of Open Wounds of the Hand. Dr. T. Tajima and associates, Niigata University Research Group of Hand Surgery;

Operative Treatment of Volkmann's Contracture. Dr. K. Tsuge, Okayama University;

Functional Anatomy of the Hand: Part I, Volar Aspect; Part II, Dorsal Aspect. Dr. T. Tajima and associates, Niigata University Research Group of Hand Surgery.

Summaries of the papers presented follow:

Anatomical Variations of Muscles and Tendons of the Hand. Dr. S. Matsui [1], in an anatomical study, found that the palmaris longus was absent in three (2.6 per cent) of 116 hands; the tendon of the extensor pollicis brevis extended to the distal phalanx in sixteen (26 per cent) of sixty-two hands; and the abductor pollicis longus had accessory insertions in fifty-one (88 per cent) of fifty-eight hands. The tendon of the extensor indicis communis was rarely found to have an intertendinous connection to the other digital extensors, and the flexor tendons of the index finger were connected only by a thin, loose membranous structure.

A Roentgenographic Analysis of Wrist Movement. Dr. S. Toriyama [2] and associates examined seventy wrists and found that more motion was present in the radiocarpal joint on dorsiflexion than on volar flexion. The most motion, however, was in the radial and ulnar deviation.

Electromyographic Study of Thumb Movement, Especially of the Paralyzed Hand. Dr. N. Nanagawa [3] and associates.

The Metacarpal Arch in Pathological Conditions. Dr. K. Kawaguchi [4] described variations in mobility of the arch in ulnar palsy, poliomyelitis, burns, and congenital deformities.

Evaluation of Disability in the Hand with Amputated Fingers, with Reference to

1. Kyushu University.
2. Nihon University.
3. Osaka University.
4. Hirosaki University.

Functional Accommodation. Dr. K. Hamazaki [5] and associates said that with loss of a digit, a compensatory increase takes place in mobility of the remaining joints, and strength of pinch is increased in the fingers adjacent to the lost digit.

Functional Test of the Hand. Dr. S. Matsuda [6] and associates found that tests of grasping, pinching, and picking up of small metal balls were valuable in evaluating recovery and in encouraging patients to improve function.

A Study of Grasping Power. Dr. T. Egawa [7] and associates used various modifications of sphygmomanometers to measure grasping power.

Statistical Study of Congenital Anomalies in the Upper Extremities Seen Over a Six-Year Period. Dr. J. Mizuoka [8] and associates observed 144 cases of congenital malformation, 0.6 per cent of the total out-patients visiting the orthopaedic clinic. Syndactyly was slightly more common than polydactyly, the latter being usually in the form of a bifid thumb. There were six cases of radio-ulnar synostosis and two cases of club-hand; other deformities were found in the usual numbers.

Statistical Observation of Malformations and Skeletal Changes in the Hand. Dr. Y. Sugiura [9] and associates observed 102 cases of malformation over a three-year period. In contrast with the previous authors, they found polydactyly the most common anomaly (thirty hands). There were two cases of Apert's acrocephalosyndactylia, nine of symbrachydactylism, and two of symphalangism. Also studied were 6,295 healthy school children, with a remarkable finding of brachymesophalangy of the little finger in 14.9 per cent of the boys and 24.6 per cent of the girls.

Congenital Flexion Deformities of the Thumb. Dr. H. Yamashita [10], Dr. Y. Hasegawa, Dr. H. Tsuboi, and Dr. T. Miura saw ninety-six cases of trigger-thumb (127 thumbs in ninety-six infants) and four cases of congenital clasped thumb over a five-year period. In three of the latter, the extensor pollicis brevis tendon was underdeveloped and deviated to the ulnar side. The authors recommended transfer of the extensor indicis proprius for congenital absence of the extensor pollicis brevis.

Trigger-Thumb in Children. Dr. H. Fukase [11], Dr. T. Fukada, and Dr. S. Yamaguchi, over a ten-year period, treated trigger-thumb in fifty-eight children, the majority under three years of age. True snapping was seen in only eight children; in most, the thumb was locked in flexion. Operative treatment gave the best results.

A Case Report of Triphalangeal Thumb. Dr. M. Morozumi [12] and Dr. N. Nishi corrected bilateral triphalangeal thumb in a ten-year-old girl by wedge osteotomy, and reported satisfactory results.

An Operative Method for Bifid Thumb. Dr. T. Kotani [13] and Dr. T. Hayashi used the Cloquet operation on two patients, one an adult, with satisfactory results. The other patient—a one-year-old—has not been followed sufficiently long to prove that growth deformity will not occur.

Deformity of the Fingers Following Operative Correction of Congenital Syndactylia. Dr. K. Ri [14], Dr. T. Onizuka, Dr. W. K. Lee, Dr. I. Abe, and Dr. Y. Sugiura studied sixty-two patients to determine which factors altered the postoperative condition after correction of congenital syndactylism. They found that the zig-zag incisions and free skin grafts used in the older-age group resulted in less deformity.

Statistical Observations of Hand and Forearm Fractures. Dr. N. Suge [15] and Dr. M. Okazaki reported on 257 patients with various fractures seen during a three-year period.

5. Kyushu University.
6. Iizuka Hospital.
7. Osaka University.
8. Kumamoto University.
9. Nagoya University.
10. Nagoya University.
11. Kyoto University.
12. Kosei Hospital, Tokyo.
13. Osaka Shiritsu University.
14. Tokyo University.
15. Iwate University.

Observation on Phalangeal Fractures Combined with Soft-Tissue Damage. Dr. K. Hosono [16] and Dr. S. Saito found that union was present clinically in most fractures within three to four weeks; it took longer, however, if fracture was accompanied by dislocation.

Fracture of the Carpal Scaphoid. Dr. T. Takeyama [17], Dr. M. Aoki, Dr. T. Matusumaru, and Dr. T. Masutani reported on seven cases of non-union in patients between fifteen and twenty-seven years of age. Bone-grafting was used in six cases and drilling in one; the average immobilization after operation was seven weeks. An eighteen-month follow-up of three patients showed satisfactory results clinically and by roentgenograms.

Secondary Repair of Flexor-Tendon Injuries in the Fingers and Thumb. Dr. H. Akamatsu [18] and Dr. K. Tsuge studied 105 cases of flexor-tendon injury. Tendon grafts done for injuries in no man's land produced 65 per cent good results. Slightly better results, 68 per cent, were obtained for injuries in other areas. Good primary management was a contributing factor in the good results of secondary repair in all areas.

Grafted Autogenous Tendon and Its Surrounding Tissue in an Animal Experiment. Dr. K. Suzuki [19] and Dr. F. Nanjo inserted a plantaris-tendon graft into a previously prepared defect in the flexor digitorum profundus of rabbits at varying intervals. There was no normal-appearing tendon before six weeks and there was considerable fibrous-tissue reaction, except when the graft was done immediately after the defect was made.

Histochemical Studies on the Healing of Experimentally Injured Tendons. Dr. T. Hoshino [20] and Dr. T. Oki studied the enzyme activity of healing Achilles tendons of mature albino rats at three days and at one, two, and three weeks after experimental injury. Elevation of all enzymes was present during fibroblast and collagen formation. Cytochrome oxidase and succinic dehydrogenase were highest at the second week; alkaline phosphatase and adenosine triphosphate, at the third week.

Experience with Artificial Tendon-Grafting in the Hand. Dr. S. Iwauchi [21], Dr. N. Shoji, and Dr. I. Abe made eight attempts to use nylon artificial tendon and had difficulty in making a firm knot. Other disadvantages were also noted. Tetron—similar to American dacron—was thought to have greater tensile strength and a less irritating effect.

Experiences with Fowler's Operation in Long-Standing Cases of Boutonnière Deformity. Dr. A. Uchiyama [22], Dr. T. Tajima, and Dr. H. Ishida recommended a free tendon graft, passed through a transverse drill hole in the middle phalanx, criss-crossed over the dorsum of the joint, and sutured to the lateral bands. In cases of old dislocation, fusion of the joint was performed. In burns, the Fowler operation was done secondarily, after adequate skin replacement.

Experiences with Hand Injury in a Casualty Hospital. Dr. M. Iwamoto [23] and Dr. H. Tejima, who work in a large casualty hospital, concluded that a hand service should be established in general hospitals and that the experience and information of recent developments in hand surgery should be given to every surgeon.

Finger Injuries in an Electrical Appliance Factory. Dr. T. Morotomi [24] and Dr. T. Saito reported on hand injuries in a large manufacturing plant, with reference to type of injury, distribution of age and sex, and work experience of the patients.

Influence of Arm Injury on the Strength of Grasp and Pinch. Dr. A. Hiranuma [25] and Dr. N. Higawara examined patients from four to nine months after settlement of compensation for injury and found that they showed considerable improvement in grasp and pinch.

16. Sapporo University.
17. Nagoya University.
18. Okayama University.
19. Tokyo University.
20. Wakayama University.
21. Tohoku University.
22. Niigata University.
23. Iwamoto Hospital, Sendai.
24. Kyoto Furitsu University.
25. Nihon Kokan Hospital.

Treatment of Volkmann's Ischemic Contracture. Dr. K. Tsuge [26] and Dr. H. Akamatsu treated sixteen cases of contracture during a four-year period, following Seddon's principles with tendon transplantation after excision of necrotic muscle. In all cases, sensory improvement occurred without nerve-grafting.

Two Cases of Operatively Treated Ischemic Contracture, Local in the Hand. Dr. E. Marumo [27], Dr. K. Murato, Dr. N. Hirao, and Dr. Y. Shimura chose section of the lateral bands as a method of treatment. Bone-block was used to maintain correction of the thumb, covering the skin defect with an abdominal pedicle.

Functional Recovery after Peripheral-Nerve Injury in the Upper Extremity. Dr. T. Otsuka [28], Dr. T. Tamura, and Dr. M. Miyatake followed various types of nerve injuries, including ten cases of radial-nerve injury. They felt that treatment, especially functional training, should be continued until all signs of nerve degeneration have disappeared.

Result of Nerve Repair in the Upper Extremity. Dr. H. Yabe [29] made follow-up examinations of twenty-two radial-nerve, twenty-seven ulnar-nerve, and twelve median-nerve injuries to determine the factors altering prognosis. He recommended earlier operations, especially for ulnar-nerve lesions, in order to recover some intrinsic-muscle function.

Carpal-Tunnel Syndrome. Dr. N. Takagishi [30] and Dr. T. Morinaga said that despite the absence of any other reports in Japan on this condition, they found seven cases in the first half of 1960. Three patients were treated surgically, with good results.

A Case of Ganglion Causing Paralysis of Intrinsic Muscles Innervated by the Ulnar Nerve. Dr. Y. Toshima [31] and Dr. Y. Kimata, in a case report, said they found a ganglion compressing the ulnar nerve and artery proximal to the pisiform. There was sensory disturbance, as well as pain and motor palsy. Subjective symptoms rapidly disappeared after excision of the ganglion.

Test of Perspiration on the Palm in Cerebral Palsy. Dr. M. Shimizu [32] and Dr. T. Tamaoki used the ninhydrin test and described the results after pilocarpine and mental stimulation and skin pressure were recorded. Decreased flow was present on the paralyzed side in most patients; mental strain caused abnormal perspiration in all patients.

Trigger-Finger in Children and in Adults. Dr. N. Okuzona [33], Dr. K. Namba, and Dr. K. Murakami made a statistical analysis of twenty-two cases of trigger-finger in sixteen children and ten cases in ten adults.

An Evaluation of Conservatively Treated Cases of Tenosynovitis. Dr. S. Matsui [34], Dr. Y. Tsukamoto, Dr. Y. Matsumoto, and Dr. M. Morita saw 225 cases of non-suppurative tenosynovitis over a ten-year period. Sixty-seven per cent of the cases occurred in female patients, many of whom were in their twenties, a much younger age group than usually reported. Quervain's disease was seen most often; 69 per cent of the patients with this condition were cured by injection of hydrocortisone. Only 50 per cent of all patients were cured by other conservative measures.

Case Report of Dupuytren's Contracture, with Special Reference to Family History. Dr. R. Gomibuchi [35] and Dr. N. Saito said that only about twenty cases of Dupuytren's contracture have been reported in Japan. The case they reported was in a man, fifty-seven years old, with bilateral involvement and deformity noted in childhood. A similar lesion was found in a sister and in two daughters, and there was a history of deformity in a maternal grandmother. No relief was obtained from fasciotomy.

26. Okayama University.
27. Jikei Idai, Tokyo.
28. Koseinenkin Tamatsukuri Hospital.
29. Keio University.
30. Hiroshima Red Cross Hospital.
31. Osaka University.
32. Nagasaki Seishiryoikuen.
33. Nagasaki University.
34. Kyushu University.
35. Chiba University.

A Case Report of Subungual Glomus Tumor. Dr. S. Horio [36], Dr. J. Mizuoka, and Dr. Y. Oniki described a subungual glomus tumor, thirteen by eight by five millimeters, found in a woman, twenty-one years old. Pain, which had been continuous for nine years, was aggravated by changes in temperature. There was erosion of the phalanx. Surgery performed included skin-grafting.

The Development of Surgery of the Hand. Dr. J. H. Boyes [37], Guest Speaker.

Two panel discussions followed the presentation of papers. Mimeographed summaries were given to everyone in the audience, and closed-circuit television was used on several screens so that all attending could see the patients presented.

The panel discussions were:

I. Tendon Transfer in Opponens Paralysis and in Paralysis of the Intrinsic (Mainly Interossea Lumbricalis) Muscles. *Chairman*, Dr. K. Tsuge.
Reporters: Dr. T. Tamaoki and Dr. Y. Ota.
Discussors: Dr. Morotomi, Dr. Ikeda, Dr. Takagishi, Dr. Marumo, Dr. Koga, and Dr. Boyes.

II. Hand Cases on the Orthopaedic Service of Niigata University Hospital. *Chairman*, Dr. S. Kono.
Reporter: Dr. T. Tajima.
Discussors: Dr. Boyes, Dr. Morotomi, Dr. Takagishi, Dr. Tsuge, and Dr. Marumo.

The Closing Address was given by Dr. S. Kono, *President*.

36. Kumamoto University.
37. 1401 South Hope Street, Los Angeles 15, California.

ROBERT D. SCHROCK, M.D.
1884–1960

Robert D. Schrock died on August 13, 1960, in the hospital at Charles City, Michigan, near his summer home at Charlevoix. He had been hospitalized for three weeks with a heart ailment at the time he passed away, at the age of seventy-five.

Bob, as he was affectionately known to a host of friends, was born on August 22, 1884, at Delaware, Ohio. His father, William A. Schrock, was a physician; his mother was Nettie M. Patterson. Bob took his Bachelor of Arts degree at Wabash College in 1905 and his degree in medicine at Cornell University Medical School in 1912. In 1935 he married Elizabeth W. Wetherbee of Massachusetts; she and one son, Robert D., Jr., survive him. Robert Jr. is now studying medicine at Cornell, his father's Alma Mater.

Following graduation from medical school, Bob took his internship and surgical training at the New York Hospital in New York City. He showed an early interest in bone and joint surgery. When he returned to Omaha in 1917, he became associated with John P. Lord, who was then Omaha's outstanding orthopaedic surgeon.

Bob had an excellent record in World War I, serving under Lt. Col. Joel E. Goldthwait in the AEF in France. When he was discharged from the service in 1919, he held the rank of major. He first served in the New York Hospital Unit, which was Base Hospital No. 9 of the AEF. He was selected by Dr. Goldthwait to teach and train orthopaedic surgeons in the school which was set up overseas. At that time there were very few physicians trained in orthopaedic surgery. He was responsible for giving lectures and holding clinics in the operating room and wards of the military hospital in which 200 or more surgeons were given instruction. In returning to Omaha after the war and again associating in practice with Dr. Lord, he rapidly established his teaching ability, and in 1921 he was appointed to the faculty of the University of Nebraska School of Medicine. In 1932 he was made Professor and Chairman of the Department of Orthopaedic Surgery and in 1949 became Professor Emeritus.

During the 1930's and 1940's, the greatest period of development of orthopaedic surgery in the United States, Bob was an outstanding figure and contributed greatly to this development. In 1941 he was elected to the presidency of The American Academy of Orthopaedic Surgeons. He considered this to be one of the greatest honors he received during his lifetime and he made an excellent president. Before being elected to this office, he had worked actively on many committees and was very closely associated with the early organization of The Academy and some of its founders, Dr. Ryerson, Dr. Henderson, Dr. Campbell, and Dr. Dickson. Bob was President of the Omaha Mid-West Clinical Society in 1943, and of the Clinical Orthopaedic Society in 1928. He was Chairman of the Orthopaedic Section of the American Medical Association in 1935. He was a member of the American College of Surgeons, the Western Surgical Association, the American Medical Association, the Association of American Railway Surgeons, The American Orthopaedic Association, and the International Society of Orthopaedic Surgery and Traumatology.

From 1943 to 1945 he was a civilian consultant to the Secretary of War and in 1949 was a consultant to the Surgeon General of the Army. Bob always maintained a deep interest in military medicine, an interest which stemmed from his experience in World War I.

Dr. Schrock was not a prolific writer, but what he wrote was done very thoroughly; it was written to the point, and in the same clear, precise English with which he spoke. Bob was well known for his operative procedure for congenital elevation of the scapula (published in the *Journal of Bone and Joint Surgery* in 1926). This was always known as the Schrock operation and by many is still considered the best procedure of its kind. Many of his writings were on fractures, a field of work in which he was well known and deeply interested. He wrote on intra-articular fracture in 1920, the prognosis of time in the repair of fractures in 1929, and fractures of the tibia and fibula in 1934. He had several publications on the diagnosis and treatment of bone tumors and several papers on the back, the last one, "The Farmer's Back", being in 1948. These all were excellent contributions to the literature and represented profound thinking on his part.

Bob's Presidential Address before The Academy in 1941 contained a very careful review of orthopaedic surgery of that day and the activities of The Academy. Several quotations from this address typify his deep thinking and philosophy. Concerning certification by the Orthopaedic Board he stated: "This is not a hallmark of excellence in perpetuity. Products are frequently certified for a definite period of time if maintained under certain optimum conditions. Some people, like products, improve with advancing years, others deteriorate and some in cold storage remain frigidly good but no better. Orthopaedic surgeons, like human beings, are influenced by environment, necessity, ambition, health and avocational interest in other pursuits of happiness". How true are these statements and how well do we all know that Board-certified orthopaedists are not always the best and do not remain good because they are certified.

Concerning the future, Bob wrote: "If the measure of continued merit is to be maintained through our oncoming years, there need be an awareness of change, open mindedness to new concepts, elasticity in viewpoint, with a ready reception and stimulating encouragement to the newer generation whose future is in the making". Bob was always encouraging, counseling and helping the newer generation. His students and residents were devoted to him.

Concerning the second generation in orthopaedics, he wrote: "The first generation of orthopaedic leaders is almost gone. The second generation is at its peak, working diligently to bring to the oncoming generation greater opportunity; recognizing the good; skillfully guiding the erratic; accepting with tolerance the altered affairs in life, and occupying with graciousness the places of the patriarchs". His Presidential Address was scholarly, well worded, and a great tribute to him as one of the leaders of this second generation he spoke of.

Bob had a phenomenal capacity for work, combining this capacity with an unusually dynamic personality. He had a very precise manner of speech; he was small in stature and distinguished in appearance. Concerning his students and residents, one of his former residents, now a professor of orthopaedics wrote: "One aspect of Dr. Schrock's work not generally recognized was the remarkable influence he exerted on students at the University of Nebraska . . . he introduced a number

of young men to orthopaedics through a unique preceptorship program" which "allowed these students to work in clinics and operating rooms and in his private office as preceptors. Many of our present day orthopaedic surgeons first learned the importance of proper plaster application and Lane's 'No-Touch' Technique in the operating room under Dr. Schrock's exacting and somewhat demanding tutelage". Bob insisted on perfection; however, this insistence was always tempered with kindness and consideration. He was never too occupied, it is said, to find time to sit down and offer sympathetic counsel to his students. Many of his students and former residents today occupy high places in orthopaedic surgery in the United States; a large number are members of The American Orthopaedic Association. He always found time to keep up with his students and former residents and continued to offer them advice and counsel.

Bob Schrock was an ideal host. On many occasions during the period of World War II the writer enjoyed the hospitality of his home, and the pleasure of the company of Bob and Betty was hard to equal. Orthopaedic surgery has suffered a great loss, but Bob will long be remembered in Nebraska and all over the United States by his many friends, his students, and strong admirers. He was definitely one of the greats of the greatest period of orthopaedic development in the United States and played a major part in this progress.

A. R. S., Jr.

The James Spencer Speed Scholarship Foundation

In February 1960, in Memphis, Tennessee, the **Willis C. Campbell Club,** composed of men who have had their training at the Campbell Clinic, formed the *James Spencer Speed Scholarship Foundation,* the purpose of which is to promote research by giving financial assistance for education to anyone approved by the Foundation. The articles of the Foundation are based on this principle and the fund will not be restricted solely to education in orthopaedic surgery.

The Foundation represents a tribute to Dr. Speed and is an expression of appreciation for what he has done for all members of the Willis C. Campbell Club. Although donations to the fund are not restricted to members of the Club ,it is anticipated that they will continue to support the Foundation, so it may grow in size. Thus, with the passage of years, the opportunities for help in education will grow with the fund.

Photograph made at the presentation of the plaque to Dr. Speed. From left to right: George B. Higley, *Chairman,* James Spencer Speed Scholarship Foundation; R. Beverley Ray, *President,* Willis C. Campbell Club; George Y. Campbell, son of the late Dr. Willis C. Campbell; and Dr. James Spencer Speed.

At the Fifth Triennial Meeting of the Willis C. Campbell Club in Memphis, Tennessee, on October 7, 1960, a plaque engraved with the signatures of the original donors to the Foundation was presented to Dr. Speed, with seventy-six signers being present.

Officers of the Willis C. Campbell Club are: Dr. R. Beverley Ray, *President;* Dr. H.A. Bourkard, *President-Elect;* Dr. Lee W. Milford, *Secretary-Treasurer;* and Dr. Otis James, *Member-at-Large,* Executive Committee.

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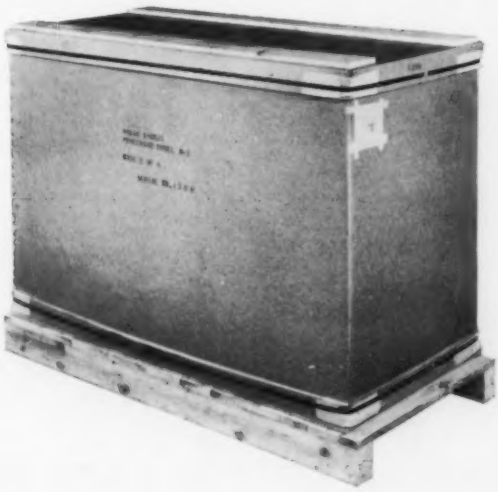

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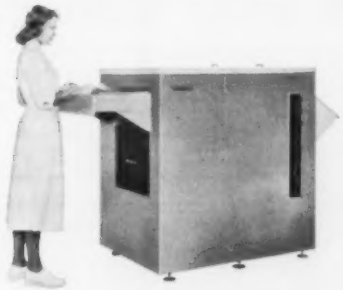

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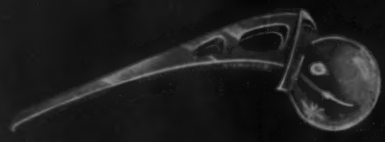

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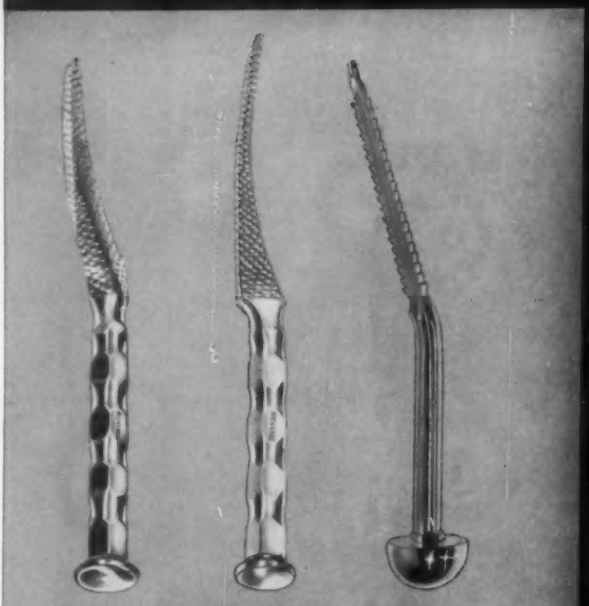

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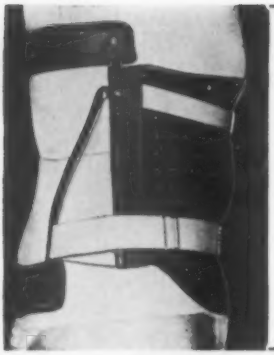

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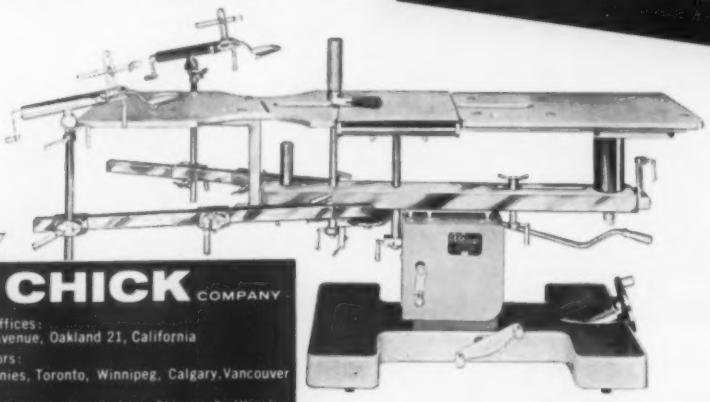

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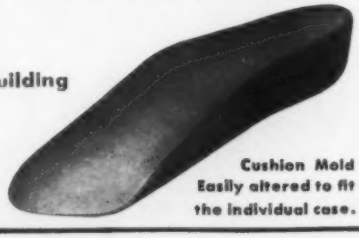

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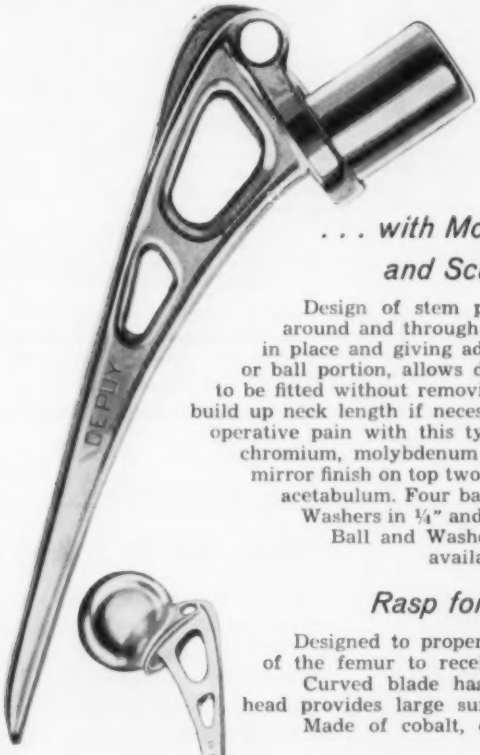

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ADDRESSES OF CONTRIBUTORS

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CHARLES O. BECHTOL, M.D., University of California Medical Center, Los Angeles 24, California
DAVID M. BOSWORTH, M.D., 742 Park Avenue, New York 21, N. Y.
COLONEL JOHN J. BRENNAN, M.C., U.S.A., William Beaumont General Hospital, El Paso, Texas
GERALD L. BRODY, M.D., The University of Michigan Medical Center, Ann Arbor, Michigan
RIDVAN EGE, M.D., Kavaklidere-Guven Sokak, Ankara, Turkey
J. WILLIAM FIELDING, M.D., 105 East 65th Street, New York 21, N. Y.
MAJOR CHRISTOPHER A. GUARINO, M.C., U.S.A.R., William Beaumont General Hospital, El Paso, Texas
CAMERON B. HALL, M.D., University of California Medical Center, Los Angeles 24, California
JOHN T. HAYES, M.D., The University of Michigan Medical Center, Ann Arbor, Michigan
FREDERIC W. ILFELD, M.D., 436 North Roxbury Drive, Beverly Hills, California
TADAO ISHIZUKA, M.D., 691, 3 Chome Shimomeguro, Meguro-Ku, Tokyo, Japan
PAUL R. LIPSCOMB, M.D., Mayo Clinic, Rochester, Minnesota
J. DRENNAN LOWELL, M.D., 275 Charles Street, Boston 14, Massachusetts
RALPH LUSSKIN, M.D., 3 East 74th Street, New York 21, N. Y.
LEONARD MARMOR, M.D., University of California Medical Center, Los Angeles 24, California
LOUIS D. RETZ, JR., M.D., Veterans Administration Hospital, Irving Avenue and University Place, Syracuse 10, New York
CARTER R. ROWE, M.D., 275 Charles Street, Boston 14, Massachusetts
HARILAOS SAKELLARIDES, M.D., 275 Charles Street, Boston 14, Massachusetts
JAMES J. SANCHEZ, M.D., Mayo Clinic, Rochester, Minnesota
O. SCAGLIETTI, M.D., Istituto Ortopedico Toscano, Florence, Italy
FRITZ SCHAJOWICZ, M.D., Maipú, 757, Buenos Aires, Argentina
HUGH SMITH, M.D., 869 Madison Avenue, Memphis 3, Tennessee
G. STRINGA, M.D., Instituto Ortopedico Toscano, Florence, Italy